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THE SCIENTIFIC MONTHLY

AUGUST 1919

FORTUNES IN WASTES AND FORTUNES IN FISH[1]

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I. INTRODUCTION.

WE have been at war with a well-organized nation which had planned and saved with war in view. In our belated endeavor to conserve existing resources and to develop new and latent ones, new problems arose and will continue to arise throughout the reconstruction period. Some of these concern fisheries and the pollution of waters. The United States Fish Commission has urged the public to eat fish, to make every day a fish day. This was no doubt done in the early days of our republic, for in a great strike of apprentices one of their chief demands was that they be not fed on salmon more than three times a week. Attention has accordingly been directed to the fact that where many fish ought to be there are few to be had. We find that fishes have greatly decreased. With only a brief survey of the situation one sees that the general problem of maintaining fishes against extensive catch and against pollution of waters with sewage and the waste products of manufactories is very complex. It is so complex indeed that in considering pollutions one may

[1] Contribution from the Illinois Natural History Survey and from the Zoological Laboratories of the University of Illinois, No. 124. For references to the literature of the subject and sources of information see, Bull. Ill. Nat. Hist. Surv., Vol. 13, Art. 12. The paper is the outgrowth of work done for the Nat. Hist. Surv.; The Dept. of Zoology, Univ. of Ill., supplied the illustrations. The writer is indebted to Professor S. W. Parr, Dr. Roger Adams and Mr. F. C. Baker for suggestions during the preparation of the manuscript.

write only from his experience and knowledge without assuming to have covered or exhausted the field.

The richness of the fish supply of our east coast in the early colonial days was beyond our wildest imagination. One early writer said of the shad of the Delaware and Susquehanna rivers, "They came in such vast multitudes that the still waters seemed filled with eddies, while the shallows were beaten into foam by them in their struggles to reach the spawning grounds." They swarmed every spring from mouth to headwaters of every river from Maine to Florida. Shad was undoubtedly the most important fish food in the early days of the nation. They were eaten fresh, and smoked and salted for winter use. During the spring runs people traveled long distances to shoal rivers to obtain their winter's supplies.

Along the Illinois River many years ago, buffalo-fish afforded the chief marketable species. These were caught by farmers, fishermen and others, and shipped by boat, principally to St. Louis. As no ice was used the fish frequently spoiled, or they were thrown away because the market was overloaded. Thus this great resource was depleted by careless and wasteful methods of catching and marketing.

The Atlantic salmon once entered all the rivers of New England; now it is the most expensive fish on the market. Our Great Lakes once yielded whitefish in abundance, but now the number is exceptionally small in comparison. Some of our Pacific-coast fisheries are likewise being depleted. Every stream formerly yielded fish to small boys and old men anglers. If any of these sources yielded half their original quantity it would now be counted a veritable fortune in fish.

Our fish resources have been depleted through neglect, carelessness and the pollution of waters. Such as are still left are endangered by new projects and new pollutions. There has been too much bald scientific and business sophistry in the matter. Ichthyologists, biologists, engineers, sanitarians, industrial chemists and business men, without consultation, cooperation or critical analysis, have proceeded on the basis of their imperfect and fragmentary knowledge to draw inferences as to the effect of this or that on fishes. The inferences of some scientists are not especially more in keeping with an equitable decision relative to a policy favorable to the public interest than was the exclamation of a manufacturer when confronted with a law intended to stop his factory from polluting streams: "What, stop a great industry because of a few fish!" The pollutions of manufacturing plants and city sewage have greatly

aggravated the depletion, or in some instances have completed the destruction previously started by heedless fishermen; but the pollutions are far more serious than the initial injury because they preclude the possibility of easy recovery. We have all sinned alike until it becomes imperative that we take stock of our knowledge, now that we are under the pressure of numerous problems demanding immediate solution because of the great war and necessary reconstruction.

The damage done in our fresh waters by pollution and obstruction of streams with dams with no adequate fish ways is almost incalculable. The great increase in manufacturing in the past fifty years has loaded our streams with poisons which have seriously furthered the destruction of fishes that were formerly available everywhere. To be sure the Mississippi and its larger tributaries supply fish, particularly carp, in quantity to the market and in the Illinois River, for example, the number of fishes at points about 200 miles or more from Chicago has been increased by increasing breeding grounds and the fertilizing of the waters by the Chicago sewage. When one considers that fishes have been wiped out for about 120 miles to bring an increase this far down the river, the gain proves after all to be a loss. The importance of pollution has been little realized in America, but progress along these lines has been very slow everywhere.

In Scotland about the year 1220 it was ordained that from Saturday night to Monday morning it should be obligatory to leave a free passage for salmon in all the various rivers. Almost seven hundred years later a very similar law was enacted in certain of our Pacific states, but the time is shorter, being from Saturday night to Sunday night. The absence of such laws in New England a century ago has caused infinite damage to salmon and shad resources.

In 1606 an act passed by James VI. of Scotland forbad the pollution of lochs and running streams because it was hurtful to all fishes bred therein. The punishment for violations were severe. Three hundred and twelve years later we are confronted with a problem of substituting fish for beef, pork and mutton and find our laws no better than the laws of three to seven hundred years ago and the native fish supply very much reduced through heedlessness and pollution with waste.

These wastes are numerous and have been less often preserved in America than elsewhere.[2] Tar is an important waste substance. At one time coal-tar was considered a nuisance in

[2] See "World Wide," Toronto, November, 1917.

gas-making, difficult to handle and difficult to dispose of. Tar is to be looked upon as the prize among waste products. It is unlikely that anything furnishing such an enormous number of useful substances will again be found nor can the enormous wastage of them in America be repeated again. The number of chemists who have investigated this substance is, of course,

FIG. 1. Diagram showing, in the form of a tree, the various wastes and the useful substances into which they may be manufactured or which may be obtained from them.

enormous. It was in 1856 that Sir William Perkin produced the first dye to be made in large quantity. He was a successful business man as well as a chemist, and built and operated a dye factory in England.

There are numerous interesting cases of waste products that have proved gold mines to men who have found ways of

turning them into something useful. The volatile substances given off in the making of charcoal from wood, for example, have become very important. In the old way of making charcoal all these valuable products (wood alcohol, acetone, acetic acid, etc.) were entirely lost, but to-day they are the most im-

Fig. 2. Diagram showing the various wastes and the damage they do when not properly recovered.

portant of the substances obtained. The investigation of waste materials is often very fascinating, and sometimes leads to unexpected ends. This was the case with the waste earths from which materials used in the making of incandescent mantles had been removed. Small mountains of these wastes were

accumulating and Baron von Welsbach went to work to investigate them for oxides other than those used in the manufacture of mantles. By means of electricity he reduced some of these oxides, obtaining certain lumps of metal. In cutting a lump with his knife, he discovered a remarkable sparkling effect. He soon saw that this had commercial possibilities, and the outcome of it was the preparation of a form of gas lighter to replace matches. These metals have also played an important part in the great war as flares for lighting no-man's-land and in furnishing the various types of signals. This was a very important waste product.

As the years go on waste products are constantly disappearing from European industry and to a lesser extent from American. Great competition and the lowering of prices have made it essential for factories to utilize or dispose of all their waste material, and processes that leave large margins for waste have not much chance of success. Utilization of waste is necessary in America now that we have to make up for the enormous wastage of war.

Perhaps most of what one may call the sensational discoveries with regard to waste substances have already been made; but there is still a great field for research both in recovering useful substances and in rendering residues harmless to animals. There is the wood-pulp industry, for example. Over 145,000 cords of pulp-wood, valued at $800,000, were lost annually in Canada, and also large quantities of sulphur from the chemicals used. The waste liquors containing these substances have been discharged into rivers or the sea and are very poisonous to animals. There is a good opportunity to utilize sawdust, and to get more value out of it than in the past. It has been used for making artificial silk, and also for manufacturing alcohol. If alcohol should come to be used in place of gasoline for automobiles, this would, in all probability, prove a profitable means of obtaining it.

It would be a very great advantage to the tanning industry if really good use could be found for the spent tan and the various waste liquors. These are now used as fertilizer. It is agriculture that seems to get the benefit of a large number of the odds and ends of waste substances. If one can find no other use for a waste material, he can probably work it off either as a cattle food or as a fertilizer though at a very low price. But one must not pass blissfully over the damage the substances do when wasted as shown in Fig. 1 and Fig. 2. The fishes must be considered. Attention is accordingly turned to some of the specific needs of fishes and fisheries.

II. Fresh-water Fishes

1. *Their Needs.*—The presence or absence of fishes is controlled by (*a*) their ability to recognize the presence of strange or deleterious substances and to turn back when they are encountered, and (*b*) by their survival or death in situations where they can not escape the deleterious conditions. The sense organs with which they recognize strange or deleterious substances have been shown to be very elaborate and effective. Fishes recognize exceedingly minute quantities of numerous substances, for example, two parts per million of sulphur diox-

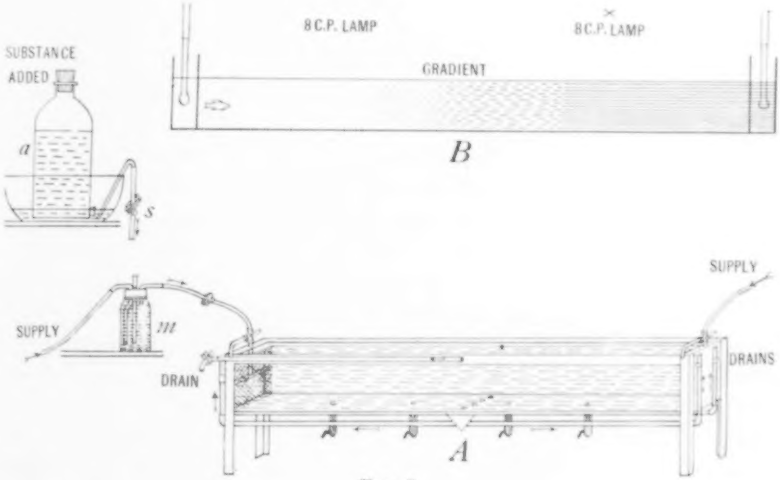

Fig. 3.

Fig. 3. Gradient Tank (*A*). Longitudinal Section of Tank (*B*). Fig. 3, *A*, The gradient tank and apparatus for introducing substances into one end. The water flows into the two ends of the tank from a common source. The flow is adjusted with a pinch cock on a rubber hose at the right-hand end, for example, at 500 c.c. per minute. This is done by turning the 3-way valve so as to run the water outside of the tank through the small spout which ends at the water level just outside of the tank. The water can be caught here in a graduate for a definite length of time and the flow per minute determined. The flow of water at the end into which the substance is added may be set at, say, 400 c.c. per minute and then sufficient of the solution added to the mixing bottle from the siphon above at the left (100 c.c.) to make this 500 c.c. also. The solution of a non-volatile substance is siphoned (see Fig. 1, *A*) from a dish in which is a 12-liter aspirator bottle (*a*) with the upper opening tightly corked and the lower one open. When the water in the dish falls below the level of the lower opening a few bubbles of air slip in and the same amount of fluid flows out, thus maintaining a constant level in the dish as long as the supply in the aspirator bottle holds out. Volatile substances have usually been added directly from the lower opening of the aspirator bottle. In this case it is necessary to correct the flows occasionally. The solution is run into a mixing bottle (*m*) which is connected in the flow of pure water. Fig. 3, *B*, shows a longitudinal section of the tank when a substance is introduced at the left-hand end. The substance is shown by black markings. The central portion shows a gradient between pure water (white) and the introduced substance (black lines). The graphs are drawn on the basis of the position of the fish in this longitudinal section.

ide, and not only turn back upon encountering them, but are able to recognize and orient their bodies with reference to increases and decreases of such substances often present in water.

The testing of these sensibilities of fishes has been carried on by means of experiments performed in a gradient tank, as shown in Fig. 3, *A*. Water of two kinds was used in the experiments. One kind was allowed to flow into one end at a definite rate and another kind into the other end at the same rate. The mixture flowed out at the middle, at the top and at the bottom so that the two kinds of water met at the center. The outflow at the center did not of course prevent the mixing of the two kinds of water in the tank and thus the middle section (broken line area in Fig. 3, *B*), equal to one half or one third of the tank, was a gradient between the two kinds of water. The tank used in these experiments was 122.3 cm. (49 in.) by 15 cm. (6 in.) by 13 cm. (5¼ in.) deep. The front wall was of plate glass and a plate glass top was used at times. Water was allowed to flow in at both ends at the same rate (usually 600 c.c. or about a pint per minute) through tee-shaped tubes, the cross bars of which contained a number of small holes. The cross bars of the tees were at the center of the ends of the tank behind screens. The drain openings were located at the center near the top and in the bottom. The outer openings of the drain tubes were at the level of the water in the tank. The water flowed in at the ends and drifted toward the center and flowed out through the drains. We found no evidence that fishes react to the slight current thus produced. Since each half of the tank held about nine liters (9½ quarts), it required 15 minutes to fill it or to replace all the water in one of the halves. The tank was enclosed under a black hood. Two electric lights were fixed above the center of the two halves, *i. e.*, above a point midway between the screen partition and the center drains. The light was 15–20 cm. (6–8 in.) above the surface of the water which was 13 cm. (5¼ in.) deep. The room was darkened during the experiments which were observed through openings in the hood above the lights or through the glass side late at night. Fishes do not usually note objects separated from them by a light.

Water differing as little as possible from that in which the fishes usually live was used for control readings. Controls were observed and the conditions in the two ends of these were the same either because the water introduced at the two ends was alike or because no water was run into either end (stand-

ing water). In the control experiments the two ends of the tank were alike and the fishes moved back and forth symmetrically (Chart I., Graphs 1 and 3; Chart II., Graph 5). When a gradient between two kinds of water was established, fishes put into the tank tend to go back and forth and thus encounter the experimental gradient. When the change of conditions thus encountered was such as to affect the fishes, they usually reacted either by turning back or by passing through the gradient into the treated water. But in the latter case they quickly returned to the untreated water, thus spending a shorter time

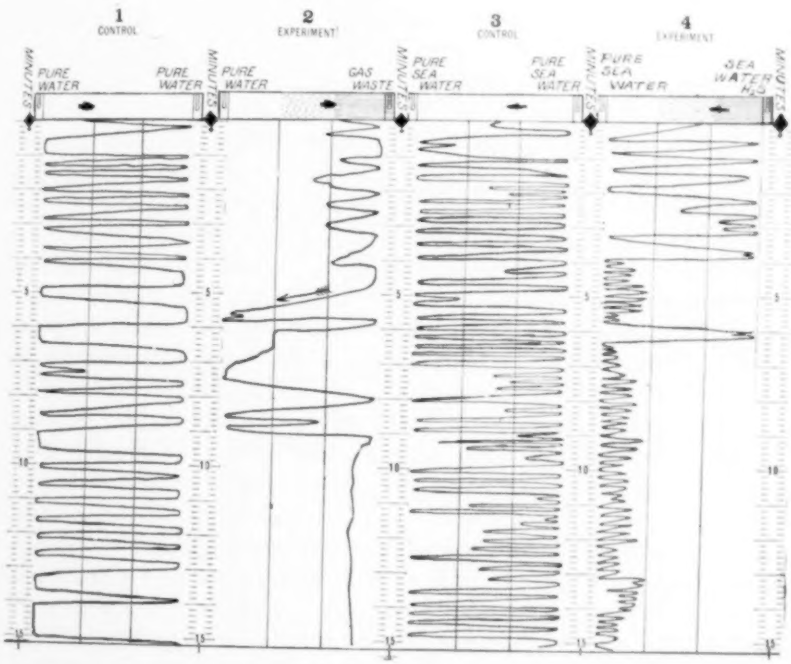

CHART I. Showing the movements of fishes in the gradient tank shown in Fig. 3 (A and B). Fig. 3, B, is repeated at the beginning of each graph; where the water was alike in the two ends it is shown clear. The kind of water is indicated above the figure. The scales at the sides are minutes divided into ten second periods. The fish is shown in black above the beginning of each graph and headed in the direction which the graph shows that it is moving. The back-and-forth movements of the fish are shown by the tracings from right to left in the graph. The length of time spent in moving, turning around standing still is indicated by the time scales.

GRAPH 1. Showing the nearly regular back and forth movement of a sunfish in pure water.

GRAPH 2. Showing the preference of the same sunfish for water containing gas waste and its turning back from purer water. The arrow indicates that it was driven into pure water.

GRAPH 3. Showing the nearly regular back-and-forth movement of herring in pure sea water.

GRAPH 4. Showing the sharp avoidance of sea water containing a little H_2S, after a few trials of the entire length of the tank.

in the treated water. In either case they are called *negative*.

Several species of fish,—large and small mouthed black bass, green sunfish, blue gill, crappie, golden shiner, sucker, and various minnows, were studied in detail. All these fishes were slightly negative or indefinite in their reaction to water containing little dissolved oxygen, *i. e.*, they turned back from or ignored water of low oxygen content. All the fishes were decidedly negative in their reaction to increased carbon dioxide. The differences tried varied from 5 c.c. ($\frac{1}{3}$ cu. in.) to 60 c.c. of dissolved gas per liter above that in which the fish had been kept. When increased carbon dioxide accompanied low oxygen the negative reaction was very marked; the fishes turned back when the gradient was encountered and only rarely entered the part containing the highest carbon dioxide and lowest oxygen.

Several workers have shown that carbon dioxide is very toxic to fish. It appears to be much more so than corresponding differences (24 c.c. per liter) in oxygen content. Fishes turn away when they encounter an increase of as little as 2 c.c. per liter. Since a large amount of dissolved carbon dioxide is commonly accompanied by a low oxygen content, and other important factors, the carbon dioxide content of water or more precisely the acidity or hydrogen ions (strongly alkaline waters excepted) is probably the best single index of the suitability of that water for fishes. Most species probably can not live where it exceeds 6 c.c. per liter during the breeding season.

2. *Breeding Requirements of Fresh-Water Fishes.*—Nearly all fresh-water fishes deposit eggs on the bottom. It is to the bottom that the dead bodies of organisms sink and decompose and, accordingly, at or near the bottom that poisonous products of decomposition occur in greatest quantity. Decomposition of the bodies of plants and animals results finally in gases such as ammonia, carbon dioxide, hydrogen sulfide, methane, etc., which diffuse rather slowly to the surface and into the atmosphere, and in blackened organic débris called humus. Thus the extent to which the gases occur is dependent upon the amount of decomposition and the circulation of the water. The same processes of decomposition which result in these gases consume oxygen and as a rule there is insufficient oxygen for eggs and young fishes. A small addition of organic matter may readily decrease the oxygen and raise the carbon dioxide to a point which weakens the eggs and favors fungus.

If a body of fresh water is to support the most desirable fishes it should have an area of clean sand, gravel or other ter-

rigenous bottom covered by from six inches to two feet of water and an area of emerging and submerged vegetation to supply food. It is probable that for the best results these three areas should be about equal. The terrigenous bottom should usually be free from blackened débris (humus), for this usually accompanies decomposition. There is nothing deleterious about humus provided the material in it has passed the early decomposition stages. Thus darkened bottom usually, though not always, indicates decomposition and bad conditions. Small quantities of débris may be eaten by débris-eating animals. The presence of gilled snails of the genera *Pleurocera* and *Goniobasis* in fresh water indicates clean bottoms. Various other organisms usually indicate pollution with sewage.

For many fishes an area of water more than four feet deep is relatively unimportant. The addition of sewage and other organic matter affects bottoms and therefore breeding conditions most. The young at the time of hatching are perhaps more sensitive than eggs, certainly more so than adults.

The destruction of breeding grounds in the Great Lakes is credited with the depletion of the whitefish supply. In 1871 Milner dredged eggs of the lake trout together with decaying sawdust. The eggs were attacked by fungus. In 1908 Clark expressed the opinion that through the accumulation of slow decaying woody material, water-logged lumber, and sewage, the chief breeding grounds of the Great Lakes had been destroyed and could not be recuperated. If the warning of Milner thirty-five years earlier had been heeded, they would have been much better than at present.

3. *Relation to Pollution.*—Sewage without the addition of industrial wastes merely consumes oxygen, and increased carbon dioxide and ammonia to a point where fishes can not live. It is particularly damaging to the young on account of its destruction of breeding grounds and production of conditions which can not be tolerated by newly hatched fishes. The introduction of sewage also favors the growth of fungi which destroy the eggs of fishes. Adult fishes usually avoid such contamination and hence, except where escape is not possible, adult fishes are not killed by it. Rivers receiving the sewage of large cities are rendered uninhabitable to fishes by the development of poisonous compounds just noted. The sewage of Chicago has rendered the Illinois River uninhabitable to fishes as regular residents for a distance of over 100 miles down stream. Some invertebrates are often able to live in rapids where sewage occurs because of the general aeration of the water.

The resistance of different useful aquatic animals to polluting substances varies greatly, as does also that of their living food. In the case of fish, for example, it is not sufficient to secure for making tests any fish that may be convenient. The tests of toxicity must of course be of a character to determine means of affording protection to fish, but not to fish alone; the organisms on which they feed are perhaps commonly more sensitive than the fishes themselves.

The following table, based largely on the work of Dr. M. M. Wells, gives an estimate of the relative resistance of several widely distributed species of North American fishes. While it needs careful verification by new methods, it will serve as a rough provisional guide. It is based largely on death in waters containing little oxygen and much carbon dioxide. Since fishes rank differently in resistance according to the poison in which they are killed, the immediate need for further investigation is obvious.

TABLE I

Indicating the relative resistance of a very sensitive minnow and of some common game-fishes of the eastern and central United States and of the goldfish. The resistance of the least resistant species is arbitrarily taken to be unity

Species of Fish	Relative Resistance	Species of Fish	Relative Resistance
Labidesthes sicculus (Brook silverside)	1	*Ambloplites rupestris* (Rock bass)	10
Moxostoma aureolum (Red-horse)	2.3	*Perca flavescens* (Yellow or American perch)	40
Catostomus commersonii (Common sucker)	2.4	*Lepomis humilis* (Orange-spotted sunfish)	12
Micropterus dolomieu (Small-mouthed black bass)	5	*Carassius carassius* (Goldfish or Crucian carp)	12
Micropterus salmoides (Large-mouthed black bass)	6	*Lepomis cyanellus* (Blue-spotted sunfish)	15
Pomoxis annularis (White crappie)	8	*Ameiurus melas* (Black bullhead)	45
Pomoxis sparoides (Black crappie, Calico bass)	8		

Tests of the minimum quantity of poison which will prove fatal must be made on the most sensitive stage. The strength of a chain is the strength of its weakest link. A little has been accomplished in the study of poisons; the most sensitive period is not known for a single fresh water species of which the entire life cycle has been definitely studied. There is only a little information relative to fishes of different ages.

TABLE II

Showing the relative resistance of different sizes of two species of fresh water fishes. Based on work by Dr. M. M. Wells

Species	Condition	Weight	Relative Resistance
Rock bass	CO_2 and low O_2	1.9 gram 20–40 grams	1.00 5.00
Common shiner	CO_2 and low O_2	0.6 gram 21.0 grams	1.00 3.00

The matter does not end with these biological differences but the toxicity of different substances differs greatly.

TABLE III

Showing the relative toxicity, on a basis of weight, of different substances when added to distilled water. The figures are only approximate, but the great toxicity of acids and alkalies is evident. The higher the figure the greater the toxicity of the substance. All are compared with common salt, which is taken as 100 based on gold fish work by Dr. Powers

Animals Tested	Poison	Relative Effect	Poison	Relative Effort	Poison	Relative Effect
Fresh-water fishes (based on amount required to kill in 45 min. to 3 hrs.)	Common salt	100	Calcium acid sulfite	10,000	Magnesium sulfate	15
	Hydrochloric acid	40,400	Potassium chloride	50	Ammonium sulfate	400
	Sulfuric acid	15,000	Calcium chloride	59	Sodium nitrate	54
	Nitric acid	23,000	Barium chloride	60	Calcium nitrate	118
	Carbonic acid	3,700	Magnesium chloride	77	Magnesium nitrate	105
	Slaked lime	15,000	Ammonium chloride	300	Ammonium nitrate	232
	Ammonia	30,000				
	Calcium sulfite	22,000				

The great toxicity of acids is evident. The addition of acid to water containing carbonate is accompanied by the liberation of CO_2 and though its toxicity is only about one tenth that of mineral acids, it may be released in quantities very harmful to fishes. In all such cases the precise hydrogen ion concentration should be determined. Limestone is often used to neutralize acid, sometimes to doubtful advantage.

Just after the beginning of the European war the writer undertook the investigation of the effects of wastes from the manufacture of illuminating gas upon fishes. This form of pollution is common in the streams and is probably one of the most important on account of the extremely poisonous character of the coal tar compounds. The most valuable compounds are most poisonous. Benzene, xylene, toluene are used in mak-

ing explosives and hence of much value, and at the same time they are the most poisonous compounds occurring in the wasted gas liquor in the gas plants. These substances are usually referred to as insoluble and hence likely to be regarded as not of importance in causing the death of fishes. All, however, are slightly soluble in distilled or ordinary stream water. The amount going into solution readily kills the best food fishes in a few minutes. Tarry material holds much of these substances in solution and continually gives it off. Carbon monoxide is one of the most poisonous substances in gas and remains in standing water exposed to the air and continues to kill fishes for weeks. Naphthalene (moth balls) is extremely poisonous, commonly called insoluble, but is soluble enough to kill fishes very quickly. Representatives of nearly all the groups of compounds found in coal tar and gas liquor are deadly to fishes and 90 per cent. of the deadly compounds do not repel fishes (Chart I., Graph 2). When they encounter these compounds, they do not turn back but swim into them. Afterward on encountering pure water they turn back into the poison though it causes death within a few minutes. Mixtures of the compounds are equally or more deadly. Gas liquors, tar "drip" from the pipes are very toxic, 2–40 parts per million kill the more hardy species of fish in an hour. The wholesale destruction of fishes by these wastes occurs at times especially during cold winters. The remedy for this is the complete recovery of all coal products.

4. *Examples of Destruction of Fresh-Water Fishes.*—In January, 1916, in a small river below a town of 50,000 inhabitants large numbers of dead fishes appeared at breaks in the ice. Others in a half intoxicated state were caught through holes in the ice. Three thousand pounds of fish were caught in three days but could not be eaten because of a bad taste said to resemble gas waste. The case was investigated by the Illinois Water Survey. The death of the fish according to their report was due to lack of oxygen and poisoning due to stream pollutions, brought about by sluggish flow and heavy ice cover which prevented aeration. A similar occurrence with less destruction of fish was investigated by the same bureau but the destruction was less, probably due to gas waste not being present as in the first case.

Another case investigated by the writer occurred in a large creek when covered with ice. Fishes in a half intoxicated condition came to holes cut in the ice. Many fishes were taken but proved inedible because of a bad taste. When the ice went out

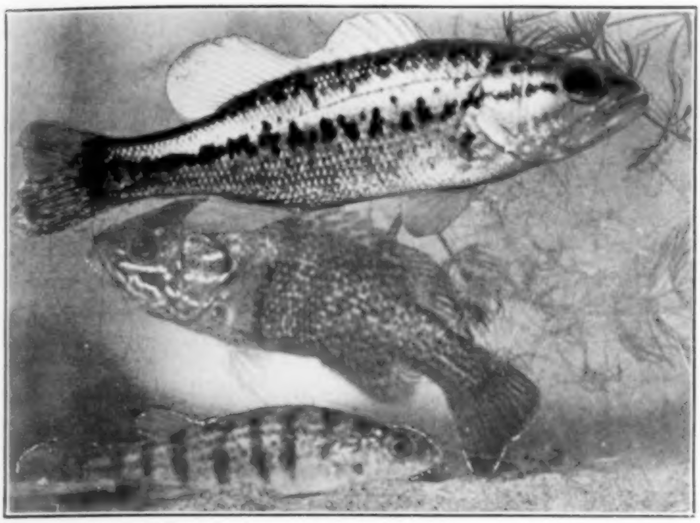

FIG. 4. Fishes common in the Calumet River before sewage was introduced. The upper fish in the foreground is a young large mouthed black bass. The central fish is a half-grown blue-spotted sunfish and the bottom fish is a small perch.

dead fishes were numerous, including carp, large and small mouthed black-bass, crappies, and sunfishes. The bullheads were the only ones which were not killed. There was a bright iridescent film under the ice and an odor of coal gas. This point is 25 miles below a community of 25,000 with a gas plant that pumps gas liquor on to the ground where it gets into the drainage sewers and into the stream. The point where the fishes were killed is a state fish preserve with special penalties for anything but very restricted fishing! The gas plant which is probably to be credited with destroying the fish did not recover anything but the heavy tar. The valuable hydrocarbons, ammonia, etc., are wasted. The destruction of fishes by industrial waste has been common throughout the country, especially within the past thirty or forty years. The fishes destroyed include those which occurred in commercial numbers, such as shad, salmon and whitefish and numerous game fishes such as perch, black-bass and sunfishes shown in Fig. 4. These disappeared in the Calumet River for a long distance below the point of introduction of sewage. Mussels (Fig. 5) survived in the rapids (Fig. 6) only a mile below the entrance of a large sewer. This is possible probably on account of the aeration of the water. The treatment of sewage with compressed air in the presence of activated sludge is effective in reducing its toxicity to fishes.

FIG. 5. Mussel shells on the bank of the Calumet showing the work of the pearl hunters. They were taken from the rapids shown below in Fig. 6. The mussels have survived the sewage which enters a mile above, probably because of the aeration at this point.

FIG. 6. Showing the Calumet River at the point mentioned above. The log in the foreground is blackened with sewage.

III. MARINE FISHES

1. *Their Needs*

Marine fishes are comparatively less resistant than fresh-water fishes to the products of decomposition in salt water

which results in carbon dioxide and hydrogen sulfide. On the whole the presence of a small quantity of carbon dioxide (lowered alkalinity) in the water affects the fishes less than a smaller amount of hydrogen sulfide. The combination of hydrogen sulfide and carbon dioxide was most rapidly fatal. Since decomposition yields carbon dioxide, consumes oxygen, and is accompanied by the production of hydrogen sulfide which also consumes oxygen, it is reasonable to suppose that on a bottom from which vegetation is absent and decomposition actively takes place, a fatal combination of lack of oxygen, and presence of hydrogen sulfide and probably carbon dioxide can develop quickly. In enclosed arms of the sea when circulation is cut off in the summer, oyster beds are sometimes killed by the presence of quantities of hydrogen sulfide. The destruction of fishes is probably not common, however, because of their negative reaction to it.

2. *Reactions of Marine Fishes*

A. *Hydrogen Sulphide.*—Herring turn back sharply from all concentrations of hydrogen sulphide not great enough to cause intoxication (Chart I., Graph 4). They avoid it sharply and turned about at a point where the concentration was equal to that under the *Ulva* on the sandy bottoms of a bay. The controls (Chart I., Graph 3, and Chart II., Graph 5) of these experiments are symmetrical, there being turnings from each end in about equal numbers. It shows the reaction of the fishes when no stimuli are encountered in the tank.

B. *Salinity and Hydrogen Ion Concentration.*—The fresh water supply of the Puget Sound Biological Station, when the experiments were performed, was from deep wells. It was very alkaline, containing no free carbon dioxide and only 0.5 c.c. per liter of oxygen. This water was aerated, which raised the oxygen to 4.8 c.c. per liter. This water was run into one end of the gradient tank and sea water into the other. In the experimental tank the difference between the density of the fresh and salt water was so great that the fresh water extended nearly to the opposite end at the top with very little mixing and the salt water occupied a corresponding place on the bottom. Thus there was a sharp gradient from top to bottom, but a very imperfect one from end to end. To avoid this difficulty a screen inclined cage was used (see headings of Graphs 6 and 7, Chart II.). The fish moved back and forth in this at a distance of about 4 cm. from the lower screen. The gradient of salinity between the acid sea water and the alkaline fresh water was

essentially perfect as shown in Chart II., Graphs 6 and 7; the oxygen content was essentially the same throughout. The salinity in the salt water end was two thirds that of normal salt water and one third in the fresh water end. Phenolphthalein indicator showed that the central region had about the hydrogen ion concentration of sea water (pH 8.0). It appears from

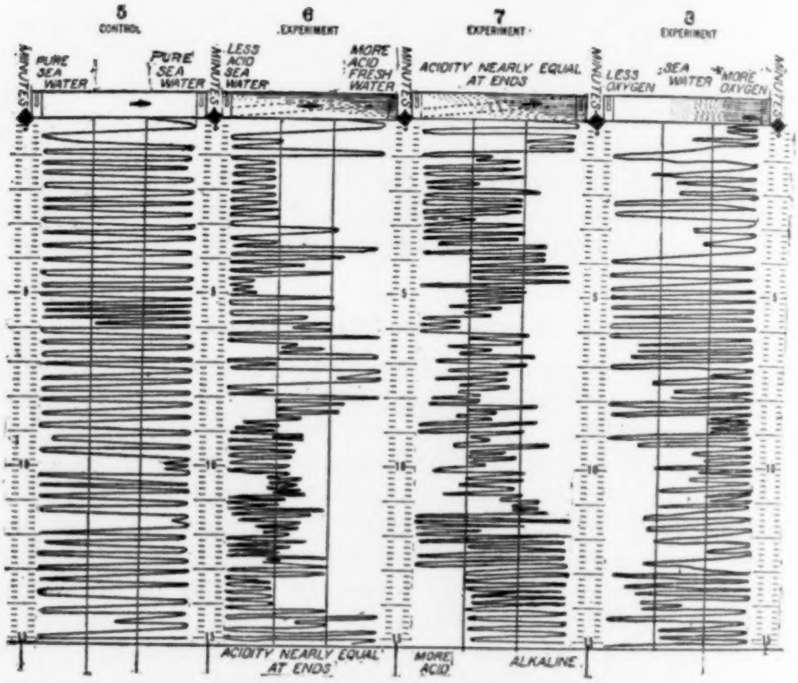

CHART II. For general remarks see Chart I.

GRAPH 5. Showing the regular back-and-forth movement of a herring in pure water.

GRAPHS 6 AND 7. Showing the selection of a less acid water and the shifting of the position of the fish from the left to the right hand end as the acidity slowly changed. In this case the herring selected the alkaline fresh water, ignoring the salt which is important to marine animals. The fish was confined between inclined screens because of the difference in density of fresh and salt water.

GRAPH 8. Showing the selection of water with most oxygen by a herring.

a number of experiments that the herring selected either brackish or quite alkaline water (pH above 8.0).

To determine whether or not this peculiarity is a reaction to salinity or alkalinity, the experiment with herring was repeated and carbon dioxide to which the fish are negative run in the fresh water, to neutralize the alkalinity. At the beginning of the experiment shown in Chart II., Graph 6, the carbon dioxide content of the fresh water was 26.5 c.c. per liter (prob-

ably about neutral pH 7.0) and the reaction was very sharply negative to fresh water. The concentration of the carbon dioxide in the fresh water was gradually lowered and the avoidance fell off, as is shown in Graph 7, which was really only a continuation of Graph 6 interrupted to take a sample which showed the carbon dioxide content to be 8.1 c.c. per liter. During the period represented by Graph 6 the negative reaction decreased gradually until a point was reached when the tank was probably about the same throughout, after which the fish became negative to the sea water at the end of 13 minutes, when on the basis of a uniform decrease, the sea water, which often has an hydrogen ion concentration somewhat greater than "normal" sea water which the herring usually prefers, became more acid than the fresh. Thus it appears that these fish are as sensitive to acidity as litmus paper. The young hump-backed salmon reacted similarly. They had just left fresh water and were caught at sea.

The relation of the two species of fishes to salinity is interesting in this connection as they ignored enormous differences entirely and reacted only to acidity and alkalinity (the herring being able to recognize the difference between pH 8.0 and 8.1). The salmon goes into fresh water to breed and some may reach maturity there or they may return to salt water at varying ages. The orientation of these specimens with head in the fresh water is of interest but it was evident that it was with reference to acidity and alkalinity (hydrogen ion concentration) rather than salinity. Sea water is less acid than the fresh water of salmon streams and the reactions of the salmon accord with their recent entrance into salt water.

The oxygen in the sea water in use at the station never reached saturation. One experiment was tried with water drawn directly from the tap, against water aerated by running over a board. The fishes selected the aerated water; the preference (Chart II., Graph 8) for the higher oxygen content was decided.

The resistance of different species of marine fishes differs as it does in the case of fresh-water fishes. Table IV. shows the relative resistance of several Pacific coast species.

TABLE IV

Showing the relative resistance of several species of Pacific Coast fishes

Hypomesus pretiosus (Surf smelt)	1
Clupea pallasii (Herring)	1.2
Cymatogaster aggregatus (Viviparous perch)	6
Psettichthys melanostictus (Flat fish)	18

3. *The Breeding Requirements of Marine Fishes*

The importance of factors which kill fishes is greatest in the early stages for three reasons. First, the small size of the eggs and embryos makes the ratio between volume and surface smallest and thus any substance in solution will reach all parts of the organism at a most rapid rate. Secondly, the inability of the eggs and embryos to move about makes them the easy victims of any adverse conditions that may occur. Thirdly, the resistance of the eggs to fatal concentrations of poison decreases to the time of hatching, being least then and rising as the fish grows larger. The eggs of the herring are deposited on the bottom. Nelson mentions rocks only and rocks are usually swept fairly clear of organic matter and the water well aerated down to the depth of one fathom where the fishes breed. If this means that sandy bottoms of bays are avoided, it prob-

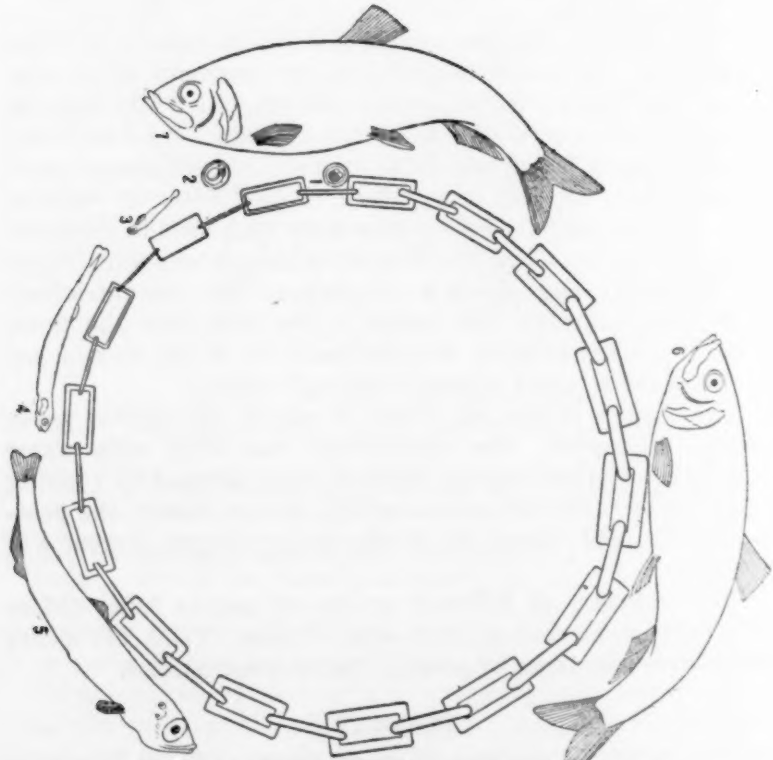

FIG. 7. Showing the life history of the European herring in the form of a circle, about a chain of links of differing strength. The weakest link is shown opposite the young at hatching but it is not known whether it should be here or at some near by point. The adults are weaker during the breeding season.

ably includes the avoidance, during breeding, of water containing much hydrogen sulfide which would be fatal to small herring fry to a greater degree than to those studied, which were 6 cm. long. Sensitiveness to hydrogen sulfide is a matter of much importance from the standpoint of the suitability of a given arm of the sea for herring and the influence upon fishes of contamination of the shores with refuse from the land. Acidity is not great in such shallow water on account of the absorption of CO_2 by the numerous plants for photosynthesis. However this does not prevent the development of much acidity at night. The eggs of nearly all marine organisms that have been studied require alkaline medium (pH above 7.0) for development. This has been demonstrated, for sea urchins, starfishes and plaice.

In the case of marine animals as in the case of fresh water ones there is a most sensitive stage. For fatal doses this falls at some time in the early free swimming stages or about the time of hatching. In the case of weaker concentration the youngest developmental stages of the egg appear to be most easily injured and rendered abnormal, which is often quite as detrimental to the species as fatal doses. Both types of effect are shown below in Table V. The life history of any animal may be represented as an endless chain (Fig. 7).

TABLE V

Showing differences in sensitivity of various stages of several marine animals. Most sensitive stage rated as 1. No basis for a comparison of the species. Based chiefly on the work of Prof. Child and of Whitley on plaice eggs

Species	Poison	Relative Resistance of Different Stages		Criterion
Starfish	KCN	Unfertilized egg	9.00	
		Blastula to gastrula	1.00	Fatal dose
		Young bipinnaria	2.00	
Sea-urchin	KCN	Unfertilized egg	3.88	
		Early gastrula	1.00	" "
		Prepluteus	1.50	
Clam-worm	KCN	2–4 cell stage	18.00	
		Larva with 2 pairs of setæ	1.00	" "
		Advanced larva	3.30	
Killifish	Phenyl urethane	2-cell stage	6.00	" "
		Hatching	1.00	
Tautogolabrus	Phenyl urethane	15 min. after fertilization	43.00	
		Heart beating	1.00	" "
		Newly hatched	1.25	
Plaice eggs	Acid	Fresh-laid	1.00	Unsuccessful development
	Acid	10 days old	10.00	
Plaice eggs	Alkali	Fresh-laid	1.00	Unsuccessful development
	Alkali	10 days old	2.00	

Different inorganic substances differ greatly in their toxicity to marine animals; acids are much more toxic to marine than to fresh water animals.

TABLE VI

Showing the relative toxicity—on a basis of weight—of different substances in distilled water. The great toxicity of acids and alkalies is evident. The higher the figure the greater the toxicity of the substance. All are compared with common salt, which is taken as 100. Based on the work of Prof. A. P. Mathews

Animals Tested	Poison	Relative Effect	Poison	Relative Effect
Marine *Fundulus* eggs (based on least fatal dose)	Common salt	100	Strontium chloride	53
	Hydrochloric acid	249,500	Sodium sulfate	97
	Potassium chloride	70	Sodium nitrate	69
	Calcium chloride	185	Potassium nitrate	38
	Barium chloride	56	Sodium hydroxide	14,610
	Magnesium chloride	113	Potassium hydroxide	6,200
	Ammonium chloride	88	Barium hydroxide	8,100

The sea water has an extraordinary capacity to neutralize acid. A liter of sea water will almost neutralize a liter of one five-hundredth normal acid and thus the toxicity of acid as shown in the table for pure water is greatly exaggerated as compared with additions to the sea.

4. *Examples of the Effect of Pollution, etc.*

(*a*) *Herring.*—By the method just described it is possible to obtain unusually accurate data on the factors influencing the movements of fishes. According to Marsh and Cobb a great difficulty in the herring fishery of the north Pacific coast is the erratic movements of the fish. Schools may visit a bay for three or four years, in succession, and then, without any apparent reason, avoid it for a season or two altogether. Bertham noted a possible relation between the abundance of these fishes and weather and suggests that climatic causes may have more to do with the failure of some branches of the fisheries than is generally believed. He attributed the failure of the fisheries of Cape Benton to the occurrence of severe east and northeast storms during the running season. It is clear that such storms may affect the dissolved content of the water by raising decomposing matter from the bottom. The English investigator Johnstone has said that it is now nearly certain that the shoaling migrations of the herring of Europe are to be associated with the salinity and temperature of the sea, but it is evident from the experiments described above that acidity and alka-

linity are more important than salinity and the solution of the problem will come from a careful study of the reactions of fishes along with a similar study of conditions in the sea.

The extreme sensitiveness of the fishes studied, as shown by their detection of slight deviations from neutrality, of small fractions of a cubic centimeter per liter of hydrogen sulfide, etc., makes it very clear that there is no difficulty in fishes determining the direction to large rivers from hundreds of miles out at sea or of finding their way into any bay or harbor or river or other arm of the sea which their particular physiological condition at a given time demands. It is not necessary to appeal to "instinct" to explain the return of certain salmon to certain rivers, or the running of herring in certain localities. The mere fact of their origin in the region, the probably limited tendency to leave it coupled with their ability to detect and follow slight difference in water is a sufficient explanation of all their peculiar migrations. The close way in which animals stay about certain localities from generation to generation is hardly appreciated. Thus, as Johnstone points out, the herring of the east coast of Britain are largely local, having formerly been assumed to belong to shoals that came from distant points.

The experimental method can not of course determine the cause for the absence of fishes from any given point but must be accompanied by hydrographic studies. Such combined efforts give trustworthy results. Hydrographic studies alone may lead to entirely erroneous assumptions because of the lack of knowledge of the sensibilities of the fishes concerned and the selection of some insignificant factor correlated with their absence or presence, as an explanation. Such correlates, offered as explanations, become the basis of erroneous remedial measures.

Noting the remarkable discriminations of fishes for differences in alkalinity, acidity and neutrality, a note of warning may be sounded in regard to the relation of pollution to runs of herring. The avoidance of the decomposition products is a sufficient explanation of the absence in valuable numbers of many other fishes. Their tendency to avoid acid waters, hydrogen sulfide, etc., which result from decomposition and are increased by the presence of refuse of fish canneries, sewage, etc., makes diversion of such refuse from the sea an important consideration. The Baltic towns of the Hanseatic League were dependent in part upon the herring industry and after a century of great growth and prosperity fell into decline at the middle of the fourteenth century. Their prosperity was the

accompaniment of the presence of great shoals of herring off the Island of Rügen in the Baltic. Their decline was caused in part by the failure of the herring industry and the supposed migration of the herring to the North Sea which has since been the center of the industry. Schouwen (on the Netherland coast of the North Sea) appears in the fourteenth century to have been frequented by the herring shoals in preference to Rügen. The rapid growth of the Netherland cities, their supremacy and final separation from the Hanseatic league followed. A little later the herring again changed their haunts, choosing the coast of Norway, where both Norsemen and Netherlanders caught them. The Beukelszoon method of curing herring having come into use, nearness to home was no longer a necessity. The Norse fisheries flourished until 1587, when an "apparition of a gigantic herring frightened the shoals away." Thus it appears that the development of the herring industry in each locality led to desertion of the locality by the fish, though the migrations assumed by historians are doubtful. Was this due to the contamination of the sea by the cities, or merely to over catch? Whichever may have been the case it is certain that contamination will not invite runs of the herring.

(*b*) *Cod.*—The cod eggs are pelagic and usually deposited in December or during the winter. The development takes place in the shore waters. The reduction of the cod supply of New England was associated with the building of dams across all the principal rivers and was attributed to the shutting out of the alewives, salmon and shad which were important articles of diet of the cod. It is far more likely that the construction of large factories which poured refuse into the sea destroyed the eggs through the lowering of alkalinity which prevents development.

IV. Present Day Problems and the War

The present great increase in manufactures and the excessively cold winter of 1917–18 with sluggish flow of streams may be expected to decrease available food fishes in inland waters. Industries using coal, gas plants, etc., are throwing much waste into streams which will destroy fish, not because they do not appreciate its value, but because being unprepared for peace they are unprepared for war.

Recently the gas company in the city of X with 25,000 inhabitants could not work up certain of its gas by-products and was storing them in reservoirs. If a market has not opened, this will find its way into the nearby stream. There was at the out-

break of the war no adequate market for coal, oil or water gas by-products. We have been and are still destroying or throwing away our most valuable coal-gas by-products. Material for munitions in enormous quantities were cast into our streams to bring untold destruction to fresh-water fishes before the war began. Until very recently under the pressure of the war there was no attempt to save these gas by-products from the smaller plants. Since interest in the by-products is increasing, many plants have attempted to save more than tar. Most of the small plants are entirely unadapted to save anything but heaviest tar and gas. The rest, with its innumerable valuable dyes, drugs, flavoring substances and explosives, is still cast into streams to kill fishes! Shortly before the war less than 25 per cent. of the coal coked in the United States was coked under conditions of complete recovery of all products. Now the percentage has increased to about fifty.

In the study of effects of pollutions on useful aquatic animals there has been too little in the way of clear statements of the problems involved. Under the pressure of the questions brought forward by the war, the writer has formulated the following nine questions involved in the solution of pollution problems.

1. In the study of the effects of pollutions test animals must be used. Is the animal selected one of representative sensiveness? The tables on fishes (pp. 108 and 115) show the need of care in selecting test animals. The common suckers are recommended as suitable fresh-water animals for tests. They are widely distributed, easy to obtain, easy to recognize, and are representatively sensitive. It is also comparatively easy to determine accurately when an individual is dead. Dr. Powers found that to touch the tip of the tail of a fish to acid would determine whether or not it was dead. Herring are representatively sensitive marine fishes.

2. What is the most sensitive stage in the life history? (See pp. 109 and 117.)

3. When is the pollution most concentrated?

In fresh water, pollution will, as a rule, be most concentrated during seasons of drought or in extreme low water in winter; but to this rule there are many exceptions. Pollutions which float will do most damage during storms or high winds. This source of danger is greatest in the sea. Ice in winter prevents aeration and hinders circulation, and seems to have been responsible in Illinois for important losses of fish due to pollution. Many poisons are more toxic at high temperature than at low.

4. What is the toxicity of untreated polluting effluents; of each residual of processes of partial recovery; or of treatment by additions to the effluent? This can be determined by extensive experimentation only.

5. Do animals turn back from the polluting substance and thus escape destruction, or do they swim into it and die? (See p. 105.)

The acids from munition works have attracted attention of late. An effluent composed of 0.13 to 0.4 per cent. of acid—a mixture of 2 parts of sulfuric acid and 1 part of nitric acid—is discharged by guncotton works. This acid effluent flowing into the brackish waters of the coast of New Jersey repelled the killifishes, on which the keeping down of mosquitoes depends. It was proposed to treat the acid effluent with lime, and the question of the effect of the calcium nitrate on marine fishes became a problem for immediate solution. A number of tests of herring and viviparous perch in the summer of 1918 showed that they are attracted by the calcium nitrate. Similar problems are arising in connection with inland rivers. Large quantities of such acid is now being run into the Sangamon River by munition works at Springfield, Ill., and into various other waters of that State.

6. Do polluting substances cover the bottom and make conditions unfavorable for eggs?

The majority of important fresh-water animals—mussels, which furnish pearl for buttons, whitefish, bass, sunfish, etc.—are dependent on the bottom for breeding, living conditions or food. If the contaminating substances are covering breeding bottoms of bare sand and gravel they are dangerous to fishes.

7. If the supply of useful animals is depleted will recovery be rapid or slow?

Petersen and Jensen found that if the flora and fauna were removed from marine bottoms useful animals such as oysters can not again live on them until a series or succession of plants and animals has prepared the way. The same is true of fishes in fresh water. A body of water deprived of all its vegetation, with the associated animals, requires much time for recovery. It is not simply the useful animals that must be taken into consideration, but the entire association of plants and animals.

8. Can correct decisions be reached without investigation of individual cases which arise?

Decisions relative to all the preceding points must usually be reached on the ground. Waters differ in their capacity to neutralize the effects of effluents, in the maximum and minimum

flow, and in their dissolved content. Samples of water should be taken with reference to the particular animal-problem in hand.

9. What is the real value of the waste when the amount of the damage which it causes is added to its commercial value?

One continually hears it said that the recovery of this or that waste product does not pay; this is an all-sufficient reason for not recovering it and the matter is usually dismissed forthwith. We need an entirely new view-point, and a new system of bookkeeping. The value of any waste product is its commercial value, when properly recovered, plus the amount of loss it occasions when unrecovered. Practically all kinds of waste may be made into something useful. Why is it not recovered? I attempted to answer this question when asked by myself of a widely known consulting engineer the other day, by saying that it would not pay. He remarked that, in his experiences, this is not the answer. The manufacturers more often do not care to spend any energy in dealing with the matter. Their object is to do the primary thing in hand and to get rid of the by-products as easily as possible. Here a sense of obligation to act in the interest of the public is needed. It has been estimated that the sewage of ninety-seven cities of more than 50,000 inhabitants, treated by the Miles process, would yield per year as follows:

Fertilizer	97,393,680 tons.
Ammonia	4,869,684 tons.
Grease	25,780,680 tons.
Glycerine	1,289,039 tons.

Recovery plants have not been installed, however, because critics of the conservation plan maintained that the profits will be less than its friends have predicted. As has been true in most other cases, calculations of the cost of suitable recovery plants and of the value of recovered products have probably been made with only minor regard to public health, and with little reference to the damage which the remaining effluent may do to fishes. In correct calculations the value of the recovered products and the benefits to public health would both be regarded as credits. The dangers to fisheries from the residual acid effluent can probably be turned to benefits if sulfur dioxide is used and the residual effluents aerated before being turned into the streams.

Aside from these nine questions which are a basis for the determination of a policy for biologists generally and for fisheries men in particular, the legal situation relative to stream

pollutions is peculiar. In most cases there are adequate laws to prevent the contamination of streams, but when the state goes into court with a complaint the offender usually says, "Tell us how to dispose of our refuse without polluting the streams and we will be glad to do so." He usually is sustained by the court, in continuing the nuisance until the complainant has shown how it can be done. In case of most misdemeanors the offender has to invent his own means of stopping the offense, but, in these cases, the state must discover it for him.

A similar condition is found in the consultation of engineers and biologists. The biologist complains of the ill effects of pollution. The engineer says, "Tell us what must be done to save the fishes and we will do it, otherwise we must ignore them." Here, as in the case of legal matters, the responsibility falls on the biologist, and in a large measure where it belongs, as the final test of all methods of treating or recovering polluting substances lies in the effects of the results on animals. These effects must be determined by experimental study. The time is at hand when fresh-water biologists must perform the experiments, discover the fundamental facts and be able to answer all these questions correctly. For sewage disposal both the Miles and the activated sludge processes afford promising points of attack. The wastage of many industrial residues is likely to be discouraged in future, but there is always something left to be turned into streams and the biologist must be at hand to determine the condition of fisheries and other biological interests in respect to them. Soon public opinion will demand these measures; eventually the battle for the fishes will be won, and when we are advised to eat fish we will be able to find them near at hand.

OUR IRON-CLAD CIVILIZATION

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Meager Resources of Early Centers of Civilization

OUR civilization is inherited from peoples who grew up in Southwestern Asia and the Mediterranean lands, regions singularly destitute of mineral wealth. Here intellectual progress far outran material progress.

The power of thought reached as great a height 2,500 years ago as it has ever attained. The scope of the mind's activities has broadened with the accumulation of knowledge but its creative power is not greater. The masters of to-day write no better literature, think no loftier thoughts, build no nobler buildings than the masters of the ancient world.

The intellectual achievements of man, as distinguished from his material achievements, find expression in the products of thought, in poetry, philosophy, religion, literature. Such attainments, depending mainly upon the creative power of the human mind, are possible in any environment which is friendly to physical and mental vigor. The essential qualities of genius may develop in an environment of meager material resources, as they did in Egypt, Babylonia, Palestine, Phœnicia and still more notably in Greece. In fact, all these centers of human development were in regions relatively poor in natural resources. The flood-plains were agriculturally rich, but Palestine, Phœnicia and Greece were poor. Italy was by no means a rich land.

Material Aspects of Civilization Governed by Kind of Materials Available

But with the material expressions of civilization the situation is different; in each country they are governed by the materials which are available. Such sculpture as Greece produced was possible only in a superlatively gifted people; but sculpture never could attain high perfection in any land where pure white marble was unknown. Marble is found in nearly every country, but marble of such whiteness and texture, such freedom from the slightest flaw, such velvety softness and translucence

of luster was found only in the quarries of Greece. The peerless marble did not produce Greek sculpture—Greek genius did that; the marble simply made it possible. Absolutely no other stone has the combination of qualities which could lure man on to such achievements. The resources included in the geographical environment of a people, or readily obtainable by them, supply the materials in which genius embodies its dreams. If parian marble is a part of the environment, it becomes possible for genius to express itself in sculpture; the environment does not decree that man shall do great things in marble, it decrees only that he may. The environment is permissive, not mandatory.

Stone a Material of Restricted Utility

Man has had to evolve his architecture and make his tools and weapons by using the materials which he could get and could work. Wood, stone and the metals have been the materials at his disposal. Great achievements could not be executed in wood; it is too weak and too perishable. Stone is enduring, but it lends itself to a limited number of uses—mainly buildings and other structures. The Romans, master builders and road makers, accomplished wonders in the one enduring material which they had in abundance—stone. There is no reason to doubt that the Egyptians and the Romans would have done great things in metals if they had had them in sufficient quantities.

Stupendous as are the pyramids, the temples of Karnak or the Great Wall of China; veritable "frozen music" as are the medieval cathedrals, the fact remains that they are passive, stationary objects challenging man's admiration and veneration; they are not mechanisms that multiply his efficiency, his power of production, or his power of further achievement. Had the materials at the service of the human race been only those in kind and quantity which the Mediterranean peoples had at their command, the story of mankind would have been so utterly unlike the story as it is, that it would not seem to be the record of the same world.

Earth's Crust Supplies Only Two Metals in Abundance

Eight chemical elements[1] make up 98 per cent. of the earth's

[1] Oxygen 47.13	Iron 4.71	Sodium 268
Silicon 27.89	Calcium 3.53	Magnesium.2.64
Aluminum ... 8.13	Potassium ...2.35	(Kemp. *Ec. Geol.* 1:699)

crust, but only two of these are metals of sufficient abundance to act as a directing influence in the world's material progress. They are iron, which forms over four and one half per cent. of the crust of the earth, and aluminum which forms over 8 per cent. None of the other metals forms as much as one tenth of one per cent. of the earth's crust.[2] Gold, copper, tin, silver, lead serve many purposes which could not be so well served by any other known substances, yet exhaustion of any one of them would soon be followed by a readjustment which would leave the modern world very much as it is now. Only two metals, then, aluminum and iron, are abundant enough to be really determining factors in directing civilization in its material aspects; and aluminum has not become such a factor, partly because the metal can not be separated cheaply from its most abundant compounds.

So accustomed have we become to the use of iron and steel for a multitude of uses that it scarcely occurs to us to ask—"Suppose iron had been a rare metal in the crust of the earth, as rare as gold or platinum, what then?" Suppose in the outworking of chemical and geological processes in the earth, iron, because of its high specific gravity, had been confined to the interior of our sphere, far from the reach of man! and suppose gold, or copper, or lead, had been so abundant as to force itself into man's operations in some such way as iron has done! As things have worked out, the material side of our present civilization is notably built up on iron. Iron possesses a marvelous range of possibilities which qualify it to serve a host of purposes which can not be served so well by anything else. From iron or steel are made the revolutionizing mechanisms or machines which have utterly changed the course of human history, mechanisms which in their various parts demand a combination of qualities of strength, elasticity, conductivity, high fusing point, rigidity, weight, or hardness which no other metal possesses.

The Ever-increasing Dominance of Iron and Steel

And so we think, if we take the trouble to consider the matter, "How fortunate that such an indispensable metal is the second most abundant one in the crust of the earth!" Indispensable? Yes, in the sort of civilization which we are born into and which we account to be the best because it is ours.

[2] Certain metals such as calcium, magnesium, sodium and potassium exceed this amount, but they are seldom used except in their compounds and for chemical purposes.

Fairly reliable historical records reach back 6,000 years. The men who built the Great Wall of China or the pyramids, or the Taj Mahal; the men who wrote the epics and chiseled the statuary of Greece; the men who founded the great religions and philosophies that have gripped the world; the men who made the Roman eagles and Roman law and discipline irresistible—carried these aspects of civilization to limits which possibly lie even beyond our attainments in these lines in the twentieth century; yet among these men iron was almost a rarity. Its chief use was for weapons of war.

As a matter of fact, iron has held a commanding position only a century. In 1740 its yearly production, even in Europe, did not exceed two pounds per capita. During the present war, its production reached 800 pounds per capita in the United States. The extensive use of iron is by no means an essential of either a high or a powerful civilization. Yet it is the one thing above everything else which has directed the course and dominated the character of the present epoch on its material side.

Only a Small Fraction of the World has Abundant Iron and Coal

While iron is the second most abundant metal in the crust of the earth, the particular geo-chemical processes by which it has been concentrated in beds of high grade have occurred in relatively few places. Five sixths of the iron ore mined at present comes from small portions of four countries, the United States, Germany, England and France. There are four or five other known areas[2] with valuable deposits. Yet all these deposits, if brought together, could be included within the borders of a small American state. Low grade ores are more abundant. It is a matter of note that, with the single exception of China, none of the highly civilized nations either of antiquity or of the earlier middle ages contained important deposits of iron. It has already been pointed out that our civilization grew up in southwestern Asia and around the Mediterranean, lands poor in iron and still poorer in the fuel for smelting it. It does no violence to realities if we imagine men and nations living on and evolving ever higher planes of civilization in an environment without coal and with but little iron, as they did for thousands of years. The only purpose of thus imagining a condition contrary to fact is that certain conditions which actually

[2] In Brazil, Sweden, China, Russia.

do exist and under which we are living may be seen in their full significance.

A little different outworking of a few chemical and geological processes might have left the iron of the earth's crust widely diffused through the rocks and incapable of extensive use; or a little difference in the history of our planet might have left it, as most parts are left, without coal. But the events that really did happen gave certain parts of the earth coal and iron in enormous quantities, yet left much larger parts with little or none.

The Marvelous Range of Utility Possessed by Iron

The great material developments of modern times have been directed in a remarkable degree by the range of possibilities afforded by the single metal iron, or more strictly speaking, the ferro-alloys. It is an impressive fact that certain of the most significant aspects of progress have been controlled and shaped along a very definite line; it has been progress in the fabrication of iron into tools, machines and engines of ever-widening variety and utility. Starting with the steam engine and progressing through all the marvelous expansion in the designing of machines of every kind, through the growth of means of communication and transportation on land and sea and in the air, means of destruction in war, means of diffusion of knowledge by the printing press, it is evident that the material progress of mankind is running mainly along those lines to which iron and steel have been devoted and to which they are peculiarly suited. There are, of course, scores of contributing factors—chemistry, metallurgy, mechanics, engineering, applications of electricity, and a long list of others—yet at every step these agencies find themselves achieving their conquests with the aid and the indispensable aid of iron and steel.

The Transition from Stone to Steel

Mankind stepped from an era in which his hightest material achievements were in stone structures—to the era of machines which multiply human energy, speed and ability in hundreds of ways. It is the marvelous range of properties that can be imparted to iron by tempering and alloying that make it the incomparable metal. By slightly different methods of treatment or by adding small amounts of carbon, manganese, chromium, nickel, tungsten, or some other element, iron can be given almost any degree of hardness, brittleness, toughness,

elasticity, rigidity or strength, and thus made to meet almost any demand ranging from the hair spring of a watch to an armor-piercing projectile. With such a substance at his command, and easily available in practically unlimited amounts, man has unconsciously come to direct his energies and his inventiveness along lines served by this metal. An age of powerful engines, powerful ships, heavy guns, gigantic dredges, towering buildings, and other things of great weight and strength has come to pass; also an age of labor-performing machines which have given us our present industrial organization of society with all its ills and blessings.

Civilization in its Material Aspects now under a New Control

With coal to supply him energy and with mechanisms that multiplied his power and his producing capacity enormously, the genius of man turned toward a new goal; not art, not architecture, not philosophy—but toward those activities in which the endless adaptations of the machine could best serve him. Master minds now found the opportunity for great achievement in a new field. The age when men of vision embodied their dreams in stone had largely passed. More and more, men of daring, of ability, of energy, saw their rewards lie in a new direction. There was no greater ability or vision than the Athenian possessed; no greater daring or energy than the Roman possessed, but opportunity of a hitherto unknown kind had developed and that opportunity and its reward lay in the activities which we term industry and commerce.

Iron and coal have not made our modern civilization. That is an outgrowth of centuries, molded and shaped by many forces and influences. It is not my desire to minimize any of the other influences which have given modern civilization its character. My purpose is to direct attention to two dominating influences: the influence of the *abundant* metal—iron, and the *abundant* fuel—coal, and to note the effect which the *abundance* of these minerals has had in determining the trend of civilization and in fixing the centers of wealth and of political and military power. The world has come under the domination of the peoples that have great reserves of coal and iron and know how to use them.

THE UPPER CRETACEOUS MISSISSIPPI GULF

By Professor EDWARD W. BERRY

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DURING the vast interval of time that succeeded the deposition of the latest Paleozoic sediments in the southeastern United States—an interval represented by thousands of feet of marine Triassic, Jurassic and Lower Cretaceous sediments in other parts of the world—this region was above the sea and undergoing denudation, slow at times and quickened at other times according as the topography changed.

This old land surface was the scene of the culmination and final extinction of the pteridosperms, ferns, calamites, lepidodendrons and sigillarias that characterized the flora of the coal measures; of the differentiation and final extinction of the fern and gymnosperm floras of the Triassic; and of the expansion and wane of the cycadophytes which were so extensively developed throughout the world during the Jurassic and Lower Cretaceous. Finally it witnessed the origin and differentiation of the angiosperms or flowering plants—the crowning achievement of plant evolution.

True flowers with gaily colored parts are thus, historically, relatively modern achievements of evolutionary activity, largely the result of the stimulus of insect activity in facilitating cross fertilization. Another feature of the flowering plants is their efficiency in the utilization of sunlight for chemical work. Exclusive of bacteria and their relatives none of the lower plant products can compare in their energy with that stored in the seeds of our cereals, nor with but a few exceptions do the lower plants produce fruits.

One is almost tempted to see design in the world-wide radiation of flowering plants during Upper Cretaceous times immediately preceding the Age of Mammals, and it is an impressive fact that but for the development of the fruits and seeds of the flowering plants during the Tertiary period man could not have progressed beyond the carnivorous pack hunting stage of the older Stone Age and civilization would have been an impossible achievement.

The total thickness of marine sediments of the Triassic, Jurassic and Lower Cretaceous of the world, missing in this

area, has been variously considered as amounting to from 12,000 to 40,000 feet and the time involved in their accumulation has been estimated as amounting to at least six million years. This estimate, while it is of necessity far from having an accurate basis, is probably an under rather than an overstatement of the actual time involved.

There is no means for determining how far out on the continental shelf to the southward the coast line extended during these geological periods that are unrepresented by exposed sediments in the southern Appalachian and Eastern Gulf Coastal Plain regions. West of the Mississippi River, however, this geographical history is not an entire blank during this long interval. In the late Jurassic sedimentary records were left in Texas and throughout eastern Mexico, showing that at that time those regions were flooded by the marine waters of the Gulf of Mexico. Again during the Lower Cretaceous the Gulf of Mexico covered much of Mexico, all of Texas and Louisiana, and parts of New Mexico, Oklahoma and Missouri, extending northward into southeastern Arizona and southern Kansas.

Geologists, both in Europe and America, are not in accord regarding the exact time in earth history when the Lower passed into the Upper Cretaceous, although abroad the consensus of opinion seems to be to consider the Cenomanian stage, as it is called, as representing the earliest Upper Cretaceous deposits. In our Western Gulf region, where the Lower Cretaceous is often called the Comanchean system, the later beds referred to the Comanchean—those known as the Washita division—have a wide extent, reaching northward as far as Colorado and central Kansas. These Washita beds carry a marine fauna that is distinctly Cenomanian in type, and the marginal deposits which contain relics of the terrestrial vegetation of that time, as in southern Kansas, furnish a flora that is also distinctly Cenomanian in character. Hence, unless we are to consider that Lower Cretaceous time in this region lasted for thousands of years after Upper Cretaceous time had been inaugurated everywhere else in the world, we are obliged to refer these Washita sediments to the Upper Cretaceous.

The early Upper Cretaceous, or what some students are pleased to call the Mid-Cretaceous, was a time of surpassing interest, not only for the student of earth history, but also for the student of bygone floras. At about this time throughout most coastal regions of the world, the strand commenced one of its periodic invasions of the old land surfaces. Almost

everywhere the resulting initial deposits of this transgressing Upper Cretaceous sea were littoral sands with clay lenses, more or less lignite, and containing fossil plants, but no remains of marine life. Whether it is the Perutz beds of Bohemia, the Gredneria sandstone of Saxony, the Atane beds of Greenland, or the sandstone of Mans in France—the latter locality giving its name to the Cenomanian stage—that are considered, all are lithologically much alike and all contain the remains of floras that are very similar throughout and which furnish many identical species of plants. The extent of the Cenomanian sea in southern North America is shown in Fig. 1.

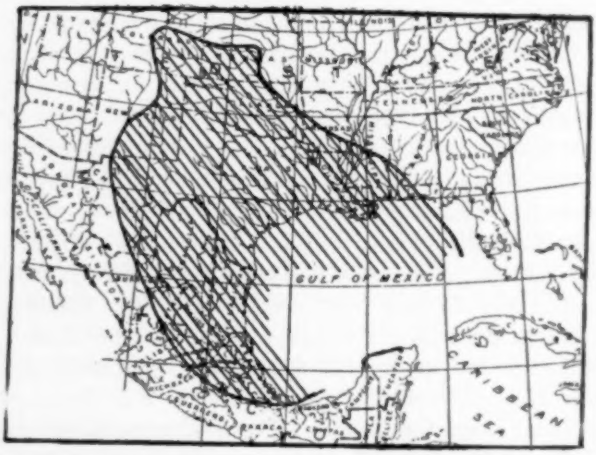

FIG. 1. THE CENOMANIAN SEA (LINED AREA) OF SOUTHERN NORTH AMERICA.

In the lower Mississippi valley and the adjacent country to the eastward we find that the long interval during which the land had been above sea level had resulted in the levelling of the country by the slow processes of erosion until the major portion was covered with the products of rock weathering and the surface was approaching a plain that sloped gently toward the southwest. This old plain is known as the Cumberland peneplain. The streams were mature in character, meandering over broad flood-plains and depositing much of their load of sediments somewhere along their courses.

At this time and possibly inaugurated by some slight warping of the crust, or perhaps caused by the actual rising of the sea level, we commence to see indications in the strata that are available for study, of the approach of the strand across southern Mississippi and southwestern Alabama. The oldest known deposits now visible in this region are referred to what is called

the Tuscaloosa formation. These are found along the southwestern margin of the present Appalachian valley, Cumberland plateau, and the Interior Highlands to the northwest of the Cumberland plateau. They occupy a roughly lunate area convex toward the southwest. This crescent shaped area of Tuscaloosa deposits extends from near Montgomery, Alabama, to the extreme northwestern part of Alabama, and reaches beyond this point as a thin and narrow band of residual sands and gravels northward across Tennessee and Kentucky.

At about the center of this crescent the outcrop of these deposits broadens until it is nearly fifty miles wide. The materials are prevailingly sandy—light-colored, micaceous, irregularly bedded sands with heavy beds of gravel made up of well rounded quartz and subangular chert pebbles. In disconnected and interbedded lenses are laminated or at times massive dark to variegated clays. Some layers are filled with the prostrate logs of drift wood, often of large size; thin bands of lignite are present at various levels, and occasional thin layers are glauconitic sands full of comminuted vegetable débris. No fossil remains have been discovered in these beds except the impressions of land plants and these are usually much broken, presumably because of their having been drifted in river waters. Occasionally more perfect materials are discovered that evidently accumulated in the quiet back water of rivers or in ponds, and that grew near at hand.

The Tuscaloosa formation is usually considered as having a thickness of about 1,000 feet, but this is calculated and not observed. Its basis is the usual method of calculating the thickness of a normal marine formation by the dip of the beds and the width of the outcrop, a method not applicable to the Tuscaloosa since it is obviously not a normal marine deposit. One can not study the Tuscaloosa with its clay lenses, its obliquely crossbedded sands, the abundance of drift wood, prevailing coarseness, widely disseminated vegetable matter, and occasional traces of glauconite, without becoming impressed with its delta-like character. It fulfils all of the requirements of a delta deposit and answers to none of the criteria of a normal marine or estuarine deposit. This obviously does not mean that at its seaward margin it did not merge into littoral, estuarine and lagoonal environments, or that on its landward side it did not extend up the river valleys as fluviatile, lacustrine, and typical continental deposits. All of these types were doubtless being formed contemporaneously and over a long interval of time, that is to be measured by the area over which

this delta-like blanket was spread rather than by the actual thickness of the sediments at any one locality. Formerly estuary conditions were considered as explaining the method of deposition of this and of similar deposits everywhere that lacked marine fossils, but there is usually but slight basis for predicating such an environment. More important were bayous, swamps, sand beaches, lagoons behind barrier beaches, and the various types of continental deposition.

The streams which brought in the sands, driftwood and carbonaceous muds came from the northeast and the bulk of the drainage of the Appalachian interior country, now a part of the Tennessee River system, flowed to the southwest at that time, the delta distributaries being located in the region where the Tuscaloosa formation is found to be thickest and its outcrop widest.

West of the Mississippi River at that time the shallow Cenomanian or Washita sea was having its margins silted up and was gradually withdrawing to the southward, leaving in its wake a mantle of littoral sands that now form a lower part of what is called the Dakota sandstone. The time when this withdrawal of the Washita sea reached its maximum corresponds approximately with the oldest known part of the Tuscaloosa delta or deltas—for there may well have been a series of deltas along this old coast. As seems to be true of all geological history the coast line, so impressive and seemingly permanent a geographical feature, did not remain in a definite position for a long time in the geological sense, but after its withdrawal it commenced a second readvance to the northward, and with this event we reach the time at which we took up the history of the Tuscaloosa delta.

As this sea advanced over the Western Interior region it formed a second mantle of littoral sands that constitute the remainder of what we now know as the Dakota sandstone, which thus becomes progressively younger in its upper portion as it is traced toward the northwest. Overlying these beach sands are normal marine shales which were also being deposited in the south earlier than in the north. The history of this Western Interior sea is beyond the scope of the present article, suffice to say that it eventually became one of the most widespread floodings of the continent that we can trace, and may even have extended until the waters of the Gulf of Mexico mingled with those of the Arctic Ocean. It broadened out medially until its opposite shores were respectively in Idaho and Utah on the west and in Minnesota and Iowa on the east. Its his-

tory was long continued and complicated, and the shores of its prevailingly shallow waters were ever shifting. Concomitant with the advance of this Benton sea as it is called over the Great Plains and Rocky Mountain country we see signs on an incipient embayment extending up the Mississippi Valley.

According to the cosmopolitan terminology of geology this stage of Cretaceous history is known as the Turonian stage from the typical development of its deposits in Touraine, and

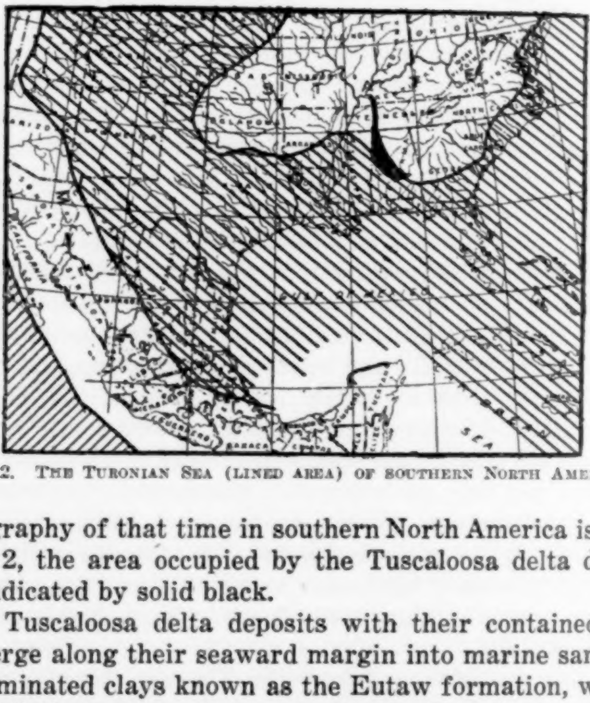

FIG. 2. THE TURONIAN SEA (LINED AREA) OF SOUTHERN NORTH AMERICA.

the geography of that time in southern North America is shown in Fig. 2, the area occupied by the Tuscaloosa delta deposits being indicated by solid black.

The Tuscaloosa delta deposits with their contained fossil flora merge along their seaward margin into marine sands and black laminated clays known as the Eutaw formation, which is then partially contemporaneous with the Tuscaloosa. Higher in the Eutaw occur massive glauconitic and more or less calcareous fossiliferous sands which have been called the Tombigbee sand member of the Eutaw formation because of their development along the Tombigbee River. This sand facies of the Eutaw seems to have been a truly transgressive marine deposit comparable with the Benton of the Western Interior sea. It eventually extended up the Mississippi embayment well across the state of Tennessee. Meanwhile history was not standing still in other regions. The warping of the surface which made it possible for this arm of the sea to extend up the Mississippi valley was naturally not without its effect upon the tributary rivers, and we assume that the Upper Cretaceous

Tennessee River had its southern distributaries silted up and gradually shifted its outlet northward. This can not be demonstrated conclusively, but the fact that the Tuscaloosa sands and gravels can be traced far to the northward along such a probable path, and the fact that these Tuscaloosa sediments in Tennessee are younger than the bulk of the Tuscaloosa deposits farther south as shown by the fossil plants points to such a conclusion. This is rendered still more probable by the additional fact that the upper Eutaw becomes more and more calcareous and finally passes into an argillaceous limestone or calcareous clay of great purity and thickness known as the Selma chalk. In this southern region immediately outside of the lunate area of maximum development of the Tuscaloosa delta deposits and separated from them by only a narrow band of Eutaw deposits there lies a similar lunate area of Selma chalk. Here the latter forms a broad band upwards of 1,000 feet in thickness and continues to the top of the Upper Cretaceous, being immediately overlain by the Eocene. Traced either eastward or northward toward the horns of the crescent the Selma chalk becomes more and more impure until it is replaced along the strike by sands and clays which have received the name of Ripley formation.

The numerous oyster-like and other Mollusca found in the chalk show that it was a shallow water deposit. It contains a very minor percentage of sandy sediments and no drift wood or other land-derived material. The bearing of this is obvious, for if the stream or streams that built the Tuscaloosa delta or deltas still flowed where they had formerly done there would have been no Selma chalk, but these slowly accumulating calcareous muds would have been completely masked by the coarser terrigenous materials brought in by the rivers. Even if a great reduction in run off be postulated, the streams would at least contribute seasonal loads of coarse sediments and the vegetable débris that such slow streams invariably carry would demonstrate their existence by lignitic laminae or by carbonaceous clays in the chalk, and these are not found. The conclusion is inevitable—that at the time the Selma chalk was being deposited the drainage of the eastern shore of the Mississippi embayment was to the northwest and southeast, where the chalk is replaced by sands and not where it had been during Tuscaloosa time.

This northward advance of the Upper Cretaceous sea up the Mississippi valley continued while the Selma chalk was being deposited farther south where its waters were clearer until

finally a broad gulf was formed which reached well into southern Illinois beyond the present mouth of the Ohio, submerging all of Louisiana and Mississippi, western Tennessee and Kentucky, southeastern Missouri, more than half of Arkansas, and the greater part of Texas except the *Llano estacado* region, which then formed a barrier that almost cut off the Mississippi embayment from the Western Interior sea.

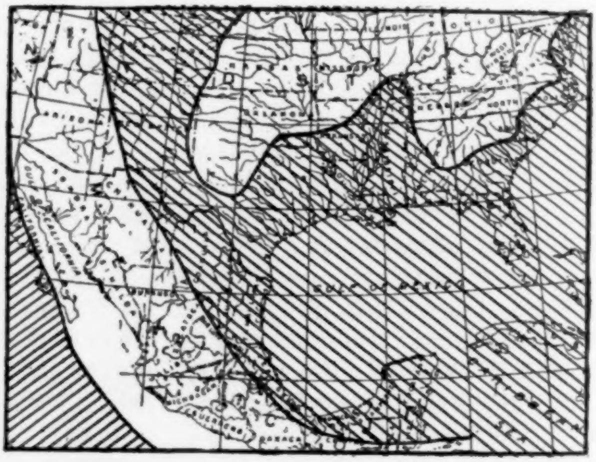

FIG. 3. THE RIPLEY OR EMSCHERIAN SEA (LINED AREA) OF SOUTHERN NORTH AMERICA.

This stage of Cretaceous history is commonly known as the Emscherian or lower Senonian stage, and the geography of that time in southern North America is shown in Fig. 3. This geographical change quite naturally had a profound influence upon the fresh-water inhabitants of the regian, and the striking contrasts between the Naiadaceæ or fresh-water pearl shells of eastern and western North America so pronounced to-day is supposed, whether rightly or wrongly it is hard to say, to date from this invasion of the sea during the Upper Cretaceous.

After this maximum advance of the Gulf of Mexico up the Mississippi valley a recession commenced which is marked by the increasingly near shore and shallow water character of the deposits, with leaf bearing clays deposited in lagoons and estuaries, with many near shore- and mud-loving molluscs like *Corbula*. Only occasionally do we find traces of a normal marine fauna of clearer waters like that found at Owl Creek in Mississippi or along Coon Creek in Tennessee. A limited area in the lower part of the Ripley sands at Coon Creek in the northeastern part of McNairy County, Tennessee, has furnished a

wonderful assemblage of marine fossils. Already it has yielded the remains of three species of fishes, five crabs and nine sea mats (bryozoa), one sea urchin, two worms, one coral and a vast host of mollusca. It has furnished what is probably the most prolific molluscan fauna that has as yet been found anywhere in our American Cretaceous, since about 350 different forms have already been recognized. Gastropods are especially abundant, embracing about 75 genera and 150 species, of which about one third are new to science, and all are beautifully preserved. This fauna contains seven Cephalopods, among which is a veritable giant of a baculite or armored squid. A mounted specimen of one of the more complete of these baculites, but not the largest that has been found, has been mounted in the Johns Hopkins Paleontological collections.

Finally, this region covered by the Upper Cretaceous Mississippi Gulf was entirely drained and remained above the sea for a long interval of time until it was covered once again by a similar transgression of the Gulf of Mexico in lower Eocene (Midway) time. Meanwhile a complex succession of events was taking place in the Western Interior sea. Its shallow marginal waters were repeatedly silted up and converted into coastal swamps in which the luxuriant vegetation of that time went to form the lignitic coals that are so widely distributed in our prairie states. Traces of this sea lingered for a long time in the deeper parts of the basin after most of the area had been transformed into a region of continental and palustrine deposition, and these conditions persisted for a long time after the Mississippi embayment had been drained.

Because of the more favorable conditions for the accumulation and preservation of the remains of the contemporaneous Upper Cretaceous floras, that of the Tuscaloosa is the most extensive and representative of any of the floras of the Upper Cretaceous Mississippi embayment deposits. This Tuscaloosa flora as it is known at the present time comprises over 150 different species, none of which survived in the Eocene of this region. Of the 87 known genera over half are now extinct, while others are no longer represented in North America, but have their surviving descendants in South America, the Orient, or even the antipodes. These 87 genera represent 48 families and 31 orders. The largest alliances are the Ranales (buttercup, custard apple, magnolia order) with 26 different species, the Rosales (rose order) with 15 species, the Sapindales (soapberry order) with 15 species, the Coniferales (conifer order) with 14 species, and the Urticales (fig, bread fruit order) with

8 species. One hundred and twenty-three of the Tuscaloosa forms are dicotyledons, similar to our modern hardwood trees, and of these 107 belong to the more primitive choripetalous division, while only 16 belong to the more specialized gamopetalous division. The largest single genera are *Celastrophyllum, Magnolia* and *Ficus.*

One of the most puzzling of the Tuscaloosa plants is shown in the accompanying figure (Fig. 4). The leaves were digitate and are seen to consist of a central symmetrical terminal leaflet and a pair of inequilateral leaflets on either side of the central one. These leaves are very abundant in the younger beds of the Tuscaloosa toward their seaward margin. It was not difficult to give them a name since they correspond generically with leaves found elsewhere in both Europe and America which were named by Saporta and Marion Dewalquea in honor of the Belgian geologist Dewalque, who first discovered them at Gelinden near Liège. Their botanical relationship, however, has never been satisfactorily determined. Saporta and Marion thought that they were related to the Hellebore tribe of the family Ranunculaceæ, while others consider that they are referable to the Aralia family (Araliaceæ) or the Bombax family (Bombacaceæ). This form, so common in the upper Tuscaloosa, has also been found in Tennessee and South Carolina, and other species are known from Arkansas, Wyoming, New York, New Jersey, North Carolina, Minnesota, Kansas, Belgium, Germany, Bohemia and Greenland, showing that it was evidently a widespread plant type during Upper Cretaceous times.

FIG. 4. LEAF OF *Dewalquea,* an extinct genus of Upper Cretaceous plant, found in the Tuscaloosa delta deposits of Alabama.

An element in the Tuscaloosa as well as in the Eutaw and Ripley floras, one that is no longer found in North America except along the Mexican border is the Cæsalpinaceous genus *Bauhinia,* now confined to the tropical and sub-tropical regions of America, Asia, Africa and Australia. Experience has shown that such modern genera as are represented in all or several tropical regions of the world necessarily have had a long geological ancestry which has enabled them to reach their present

striking confirmation of this theoretical consideration. Upper Cretaceous species, recognized by their very characteristic leaf form, have been found in both Europe and America, and Tertiary species are recorded from southern Europe. About a dozen fossil forms are known and they are especially abundant

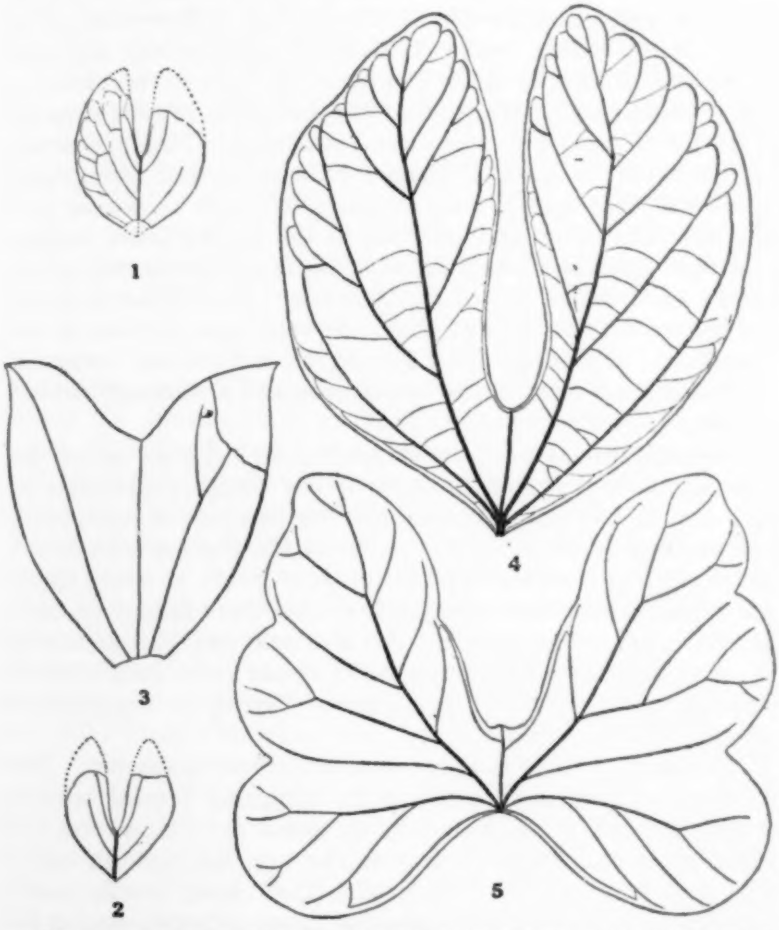

FIG. 5. LEAVES OF VARIOUS UPPER CRETACEOUS BAUHINIAS. 1, 2, *Bauhinia marylandica* Berry from the Magothy formation of Maryland; 3, *Bauhinia ripleyensis* Berry from the Ripley formation of Alabama; 4, *Bauhinia cretacea* Newberry from the Raritan formation of New Jersey; 5, *Bauhinia alabamensis* Berry from the Eutaw formation of Alabama.

and varied in the North American Upper Cretaceous. They seem to have been particularly common during Tuscaloosa time, for at several localities in Alabama leaves of both a large and a small species have been discovered which are also found at

corresponding horizons in Maryland and New Jersey. In the lower Eutaw a large and ornate butterfly-like form has been collected, while a smaller form is present in the Ripley in both Alabama and Tennessee. These are all shown in the accompanying figures.

Another Tuscaloosa plant belonging to the same family as *Bauhinia* and somewhat like it in leaf form is *Hymenæa*. The latter has leathery leaves with a characteristcally different venation and entirely divided to form two inequilateral leaflets. The modern species are trees of the American tropics yielding a variety of copal gum and a hard red wood. They are prized by the South American Indians for their sweetish sour fruits. Not more than eight or ten existing species are known, so they are less than twice as numerous as the known fossil species. In Upper Cretaceous and Tertiary times the genus was represented upon both sides of the Atlantic. Five different forms are recorded from beds of about the same age as those of the Tuscaloosa in Kansas, New Jersey, New York and Bohemia. The Tuscaloosa plant is the handsomest and most clearly defined of any of these.

Several species of *Sequoia* grew round the shores of the Mississippi embayment throughout the Upper Cretaceous, as they had in still earlier times, but the presence of sequoias is not as remarkable as it may seem to the layman who knows only the giant trees and the California redwood of recent times, for sequoias were once cosmopolitan and their foliage or characteristic cones are found in the Mesozoic and Tertiary rocks of most countries where the fossil floras have been studied. There are, however, two other types of Tuscaloosa conifers that deserve special mention.

The first of these is *Dammara* (and *Protodammara*). The modern dammaras or kauri gums comprise several species, mostly insular types, found in the area extending from the Philippines and Malay Peninsula through the East Indies to Fiji and northern New Zealand. They have mostly large, parallel-veined leaves and immense cones of single-seeded deciduous scales. Sometimes in Tertiary rocks, but especially in those of the Upper Cretaceous, kite-shaped mucronate tipped cone scales with longitudinal resin canals have been found. These baffled paleobotanists for a long time, but are now known to be those of *Dammara* and of an allied extinct genus *Protodammara* which had smaller and three-seeded cone scales. Both of these occur in the Tuscaloosa clays as well as in corresponding horizons northward as far as western Greenland and

abodes over land routes no longer in existence. *Bauhinia* is a in Europe. These occurrences prove that this now restricted type of ancient conifer was once common throughout the northern hemisphere and has gradually become restricted to its present limited habitat.

The other Tuscaloosa coniferous type that I wish to mention is *Widdringtonites*, a genus whose descendants are now confined to South Africa and Madagascar with outlying relatives in North Africa, extreme southern South America and Australia. Although foliage like that of *Widdringtonites* is recorded from rocks as old as the late Triassic, it should be remembered that coniferous foliage alone in the absence of cones is difficult to identify with precision, and while *Widdringtonites* has been identified with very many Upper Cretaceous and Tertiary outcrops in North America, Greenland and Europe, they are not all above suspicion. However, if the student is fortunate enough to discover the cones, he can be assured of the nature of his finds, for *Widdringtonites* has characteristic four-valved cones quite distinct from those of other conifers. Among the great abundance of delicate foliage of this plant preserved in the Tuscaloosa clays of Alabama are some with small, attached four-valved cones just like those of the modern forms, thus demonstrating their relationship.

One of the most spectacular members of the Eutaw and Ripley floras is the plant known as *Manihotites georgiana*, shown in the accompanying figure (Fig. 6), one fifteenth natural size. These leaves are subpeltate and of enormous size, deeply lobate and dichotomously sublobate. Naturally, when such large leaves fell into the bayous of Eutaw and Ripley time and drifted out to be buried in the mud of the lagoons, they were almost always broken to pieces, and such fragments are not uncommon and are rather widely distributed, having been found at several localities in North Carolina, Georgia, Tennessee and Arkansas. It would have been entirely impossible to determine their general form or their botanical relationship if it had not been for the accidental discovery by the writer of two nearly perfect leaves in a tiny clay lens in the lower Eutaw sands of western Georgia.

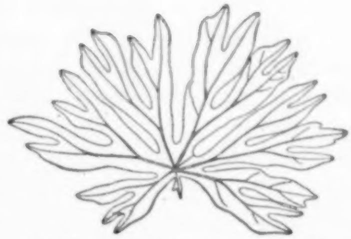

FIG. 6. *Manihotites*, AN UPPER CRETACEOUS CASSAVA LEAF FROM THE EUTAW FORMATION OF GEORGIA. ×1/15.

One of these leaves measured 36 centimeters across and the

other 48 centimeters and both apparently came from the same plant. It was at once obvious that they represented an ancestral type of the genus *Manihot*, which includes the Cassava plant, and which has upward of a hundred existing species, nearly all of which are endemic in tropical South America, the majority being found in Brazil. Various of the cultivated varieties will grow in our southern gulf states where the growing season lasts for nearly the whole year, but light frosts or even continued cool weather entirely stops growth. Even in the tropics the best growth is made in the humid coastal regions, so that if the fossil form required a comparable habitat and climate, it furnishes an interesting light on the conditions around the border of the Eutaw and Ripley seas of the Mississippi embayment.

Many other interesting extra-limital types might be mentioned which once flourished in association with the early ancestors of our native trees on the shores of these ancient seas, but enough has perhaps been written to illustrate the fascination in transporting the mind backward through millions of years, forgetful of the obtrusive present, and endeavoring to picture the pulsing life and its environment and the shifting scenes of the geographic history of remote time.

MAN AND HIS NERVOUS SYSTEM IN THE WAR. II

By Professor F. H. PIKE

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The General Results of Internal Organization

THROUGH the agency of these various kinds of organization, the activities of the organism are so coordinated or correlated that, under the usual conditions of existence, no one of the life processes outruns the others. No one process or reaction goes on unchecked or uncontrolled, but each process is regulated in conformity with the needs of the body. The organism looks after itself. This orderly coordination of internal activities of the plant or animal organism was, as referred to a few pages back, called physiological integration by Herbert Spencer. The point of view of the physiologist is that all internal processes of the organism go on for the good of the organism as a whole. As Haldane expressed it, the changes which occur in response to changing conditions are such as to perpetuate the life of the organism. This constitutes one phase of what Treviranus called adaptation—the property which, as Burdon-Sanderson believed, distinguishes living from non-living matter.

In setting forth the progress of physiology as consisting in the increase of our knowledge of the internal organization of the plant or animal body, one may see a justification of Burdon-Sanderson's earlier statement as to the proper field of physiology—"The action of the parts or organs in their relation to each other." The physiology of the past has been almost wholly concerned with the physiology of the individual, with only brief reference in a few of the texts, *e. g.*, Beaunis and Luciani, to the physiology of the species.

With the entrance of the physiology of the species into the problem, we must, I think, add something to the statement on the outcome of the processes in living matter. All the ordinary processes in individual living organisms which go on for the good of the organism may be regarded as egoistic activities, or, as some would express it, selfish activities. But when the point of view is shifted from the individual to the species, there is another group of activities which enters in, and which has reference to other individuals. This second group of processes,

since it has reference to other individuals, may be regarded as altruistic rather than egoistic. The continued existence of a species depends, therefore, first upon the successful outcome of the egoistic processes to the end that individual organisms may be present on the earth and, second, upon the successful outcome of the altruistic processes to the end that there may be new individual organisms upon the earth to take the place of those that die. There must be, therefore, a continual balance struck between egoistic and altruistic activities if the species is to survive. To anticipate a part of the discussion in later portions of this paper, we may say, also, that the new individuals must be somewhat better on an average, than the old if evolution is to occur. That evolution has occurred, there is now little doubt.

As a result of the study of the internal organization of living forms, we have gained certain ideas of the various processes or changes occurring in living organisms. Jost[17] summarizes these changes as: (1) Changes of form, including the phenomena of growth and development. (2) Changes of position, either of the organism as a whole or of its parts with relation to each other or to the organism as a whole; this includes all phenomena of movement. (3) Changes of matter and energy—metabolism in its widest sense.

The Organism in Its Environment

Until the organism comes into contact either with its environment or with other organisms, it can have little relation to other things, and, consequently, physiology as a science can have little relation to the great lines of scientific thought in general until it considers the relation of the processes of the regulation of the internal conditions of the organism to the external world. Evolution, heredity and variation, and man's mental reactions to the conditions of his environment are all matters of general biological, or even public, interest and we may inquire into the relation between physiology and these other lines of work. As a rule, the animal physiologist, as distinguished from the plant physiologist, has not considered his material from the point of view of organic evolution, and to a still greater degree, he has not considered how his body of fact will react upon the current conceptions of the process of evolution, either in the way of sharpening our ideas or of modifying them to bring them into line with what is known from the physiological or functional side of biology.

[17] "Vorlesungen über Pflanzenphysiologie," 2d., pp. 3-4, Jena, 1908.

There are certain large problems in biology which, by definition at least, belong to physiology, but which as a matter of fact do not at present form a subject of investigation by physiologists. Such, for instance, are the great questions of development and heredity, and the varied and important reactions between the organism and its environment included under the term ecology or bionomics.[18]

Yet, unquestionably, the body of fact on the functional organization of animals and plants is now sufficiently large and complete to exert an influence upon wider and more general aspects of biological thought.

The Influence of the Doctrine of Evolution upon the Development of Physiology

The doctrine of evolution has had an influence upon the development of the wider inductions of physiology in places where physiology and morphology have touched upon common ground. But the recognition of the influence of organic evolution upon the development of physiology has, on the whole, been more tardy and much less extensive than similar recognition in morphology. The science of morphology is, in fact, confessedly founded upon the doctrine of evolution, but such a statement can not yet be made about physiology. Claude Bernard included evolution as one of the fundamental properties of living matter, and Beaunis included evolution as one of the principles of physiology, but such statements have not been generally incorporated in the texts on physiology in the present century. The biologist must eventually follow the lead of the astronomer or the astrophysicist and the geologist and attempt the explanation of the evolution of plant and animal forms in terms of the underlying changes of matter and energy as the astronomer and the geologist are doing now.

A digression may be pardoned here. Claude Bernard not only saw the larger province of physiology, but he also saw the application of the fundamental principles of science to his own subject. The opinion of a neutral observer from the province of astronomy may be given here:[19]

The statue of Claude Bernard before the college must appeal to every scholar; for his "Introduction a l'étude de la médicine expérimentale," unfortunately veiled from workers in other fields by its medical title, is one of the classics of science. Here in the crystalline clearness of perfect French, devoid, in large part, of professional details, the general principles of scientific research are superbly presented. No investigator unfamiliar with this great work should leave it long unread.

[18] Howell, *loc. cit.*, p. 11.

[19] Hale, G. E., "Science and Learning in France," The Society for American Fellowships in French Universities, p. 11.

There have been times when the physiologist might stand in the presence of his fellows, as Cellini did in the studio of Francis I., and say: "I too am a scientist."

On the morphological side, the idea of evolution has influenced physiology in the development of our ideas of the circulatory, respiratory and digestive mechanisms. Many texts on physiology include brief surveys of the comparative anatomy and physiology of these systems, and there is now in the literature a considerable bulk of facts on the comparative physiology of these systems. But, on the whole, the comparative physiology is treated more from the morphological than the purely functional side.

The influence of evolution is shown also in the treatment of the nervous system. But here again the treatment of the comparative side of the central nervous system has been more morphological than functional. Edinger and von Monakow have shown that, considered morphologically, there are two nervous systems in the higher vertebrates. There is the primitive or phylogenetically older central nervous system to which Edinger has applied the term palæencephalon, present in the lower vertebrates and persisting in higher vertebrates. But higher vertebrates possess some nerve cell groups and fiber tracts which have appeared in the course of organic evolution, and been added to the palæencephalon as it exists in lower vertebrates. This phylogenetically newer portion is known as the neencephalon.

It is the phylogenetically newer portion, the neencephalon of Edinger, which is particularly related to the cerebral hemispheres, either as end stations for afferent fibers or as the site of origin of motor fibers. It follows that cerebral localization is possible in a high degree only when the neencephalon is developed in a high degree. Localization in other parts of the nervous system is probably related more to the palæencephalon than to the neencephalon.

The question of cerebral localization as well as localization in the nervous system generally has been a subject of controversy for more than four decades, and there is still no general agreement on many of the points concerned. There is little question that, morphologically, the anterior portion of the central nervous system—the brain—has undergone profound changes in the course of evolution. Steiner and others have supposed that there might be a shifting of function toward the anterior end of the nervous system corresponding to the change in structure. Gaskell emphasized the increasing importance to

the animal of the head in acquiring its experience. Goltz, however, opposed the idea of the shifting of function toward the brain and denied the validity of the theory of cerebral localization. Goltz stated his belief that the same segments of the nervous system—*i. e.*, the spinal cord, the medulla oblongata, the cerebral hemispheres and the rest—exercised essentially the same functions in all types of animals. There is no detailed and extensive cerebral localization in the frog and, on the basis of Goltz's view, there can be no more in man. Twenty years later, Edinger expressed an essentially similar view about certain portions of the nervous system. I am unable to see the validity of either Goltz's or Edinger's argument, but I have been repeatedly told that the error lies in my own way of thinking and not in any part of the Teutonic argument. I still adhere, however, to my views expressed ten years ago that the function as well as the structure of the central nervous system has undergone profound changes in the course of vertebrate evolution. I do not believe, as Goltz insisted, that the same structures in the nervous system of man necessarily have the same functions they exercise in the frog. Nor do I see that Edinger's view helps us much.[19]

Quite apart from those phases of the subject in which I have come into conflict with the weight of authority, I do not feel that the influence of the idea of evolution upon the general conceptions of physiology has been as great as it should have been.

The Influence of Physiology upon the General Conceptions of Evolution

The other phase of the question remains. What effect have the conceptions of physiology had upon the general trend of thought in evolution?

The contribution made by physiologists directly has not been large, but the application of some of the principles of physiology by biologists to the problems of evolution has been of greater extent. In recent years the plant physiologists have been attacking such problems as the effect of changes in the environment upon plants and we are now getting quantitative data on which to base our opinions. Perhaps a better way to put it is to say that we are supplanting mere opinion by statements of fact.

There is sufficient evidence from the side of physiology to show that there is a decreasing effect of the environment upon

[19] Pike, *Journal of Comparative Neurology*, 1918, XXIX., p. 485.

the internal physico-chemical conditions of organisms as successively higher types are studied. In more recent years it has been recognized that Herbert Spencer made a statement of considerable biological importance when he said the organism acquired an independence of the environment. Woods has emphasized this phase of the subject in "The Law of Diminishing Effect of the Environment" and Julian Huxley has presented the subject, partly from the point of view of the zoologist, partly from the point of view of the philosopher, in his "Individual in the Animal Kingdom." I have given elsewhere a survey of the mechanisms, considered from the point of view of the physiologist, by means of which higher animals have attained their independence of the environment.[20] I have also pointed out that this increasing independence of the environment or, in other words, the increasing rigidity of the internal organization of the organism, eventually leads to a limitation of the possibility of changes in the individual organism in the course of its lifetime.[21] From the lowest forms on up to the highest, there is an increasing rigidity of the physico-chemical organization which not only limits the effect of the environment on the organism, but which also limits the magnitude of internal changes that are compatible with continued life of the organism. Reichert has shown that changes of a physico-chemical nature constitute one of the processes of organic evolution. The conclusion follows, that, while rigidity of the internal physico-chemical organization may result in greater efficiency of the individual organism, it interferes with the progress of evolution in the individual. But Claude Bernard's statement that evolution is one of the characteristics of life seems to me essentially sound. The highly organized, efficient, but unchangeable organism dies and a new one takes its place. Efficiency demands its price.

The data accumulated by physiologists in the study of the chemical mechanisms of the plant and animal body form a necessary background for the study of the dynamic effects of changes in the environment. For until we know the constitution of the organism under standard conditions, we are not in a position to say what changes have been produced in that constitution or physico-chemical system by subjecting it to a different set of conditions.

The chemical mechanisms in the internal organization of

[20] Pike, F. H., and Scott, E. L., *American Naturalist*, 1915, XLIX., p. 321.

[21] *Journal of Heredity*, 1917, VIII., p. 195.

living forms exemplify Bergson's statement that "Life manifests a quest for individuality and tends to constitute systems naturally isolated, naturally closed." For the organism is a physico-chemical system of its own, and it tends to close itself more and more against the effects of the environment. But nowhere does the independence of the environment become complete.

The possibility of the effect of a change in the environment upon the organism is not limited to possibility of an effect upon the physico-chemical mechanisms. Des Cartes, in the seventeenth century, pointed out that the central nervous system is a mechanism capable of bringing about the coordination of the activities of the animal in response to a change in the environment.

The property of irritability is highly developed in nervous tissue, and in the higher animal organisms, we find developed at the periphery an elaborate series of receptors or sense organs whose general function is to lower the threshold of stimulation to a particular form of stimulus, or, in less technical language, to make the organism more sensitive to the manifestations of certain forms of energy in the environment. Some specific examples of these will be given further on in this paper.

Psychologists have taken up the problem of the reaction of the individual to those changes in the environment which affect the sense organs, and to which the individual responds by the exhibition of some phenomenon of behavior. Public interest in their results has been much greater than in the results on the organization of the nervous system, and the influence of the psychologists upon thought has been greater than that of physiologists. The reason for this is that the psychologist has considered the relation of the organism to the environment while the physiologist has not done so to an equal degree. But the fundamental basis for the explanation of the psychologist's results, upon which any rational interpretation of his facts must rest, is the organization of the central nervous system. Progress in psychology is, to this extent, dependent upon progress in the physiology of the nervous system.

It is sometimes a thankless task for a worker in one field to point out the indebtedness of workers in other fields. It is all the more gratifying, therefore, to be able to cite the acknowledgments of other workers of their interest, if not of their indebtedness; for when the acknowledgement is voluntary, the prospects of cooperation are greater, and most certainly the

students of the nervous system need to cooperate in the present state of science. In psychology, there are numerous instances of the manifestation of this interest. A recent example is that of Professor W. H. Burnham whose paper on "The Significance of Stimulation in the Development of the Nervous System"[22] emphasizes the relation of the organism to the environment and gives an account of the organization of the nervous system in terms somewhat different from those which I have employed.

An even stronger statement is that by Forel:

> Comparative Psychology is an as yet almost unexplored territory and but little understood, for want of approaching it by the best side, that is to say, by carefully made observations. It is involved either in metaphysical dogmas, or in shallow anthropomorphism which confounds inherited instinct and its automatisms with the plastic judgment of the individual, based upon memory and the association of memories or sensory impressions. Let us be thoroughly imbued with the truth that each species and even each polymorphic animal form has its special psychology, which should be especially studied, and which depends on the one hand upon the development of its muscles and senses, and on the other upon that of its brain.[23]

I may, then, plead the fundamental nature of the organization of the nervous system as a justification for any attempt to explain man's responses to certain changes in the environment from the point of view of physiology.

It has long been recognized in one way or another that the physiology of the nervous system can not be adequately studied without reference to the relation of the organism to its environment. This is clearly set forth by Professor C. J. Herrick in the opening chapter of his "Introduction to Neurology." Instincts have long had a fascination for biologists and I venture to quote here a statement from a French master which I have cited in another paper.[24]

> We may distinguish, in those attitudes and movements which are intended to express our intellectual and instinctive acts, and which are included under the generic term "gestes," between those which are bound up with organization and, as a consequence, are present in all men, in whatever condition, and those which have arisen and reached their perfection in a social state.
>
> The former are intended to express the most simple condition, the internal sensations as joy, pain, grief and the like, as well as the animal passions, through cries and the voice. One may observe them in the idiot,

[22] *American Journal of Psychology*, 1917, XVIII., p. 38.

[23] "The Senses of Insects," quoted by Rau, Phil and Nellie, "Wasp Studies Afield"; Princeton University Press, 1918.

[24] *Journal of Comparative Neurology*, 1918, XXIX., p. 487.

the savage, the blind from birth, as well as in civilized man enjoying all moral and physical advantages. These are native or instinctive responses.

Whitman[25] also recognized this essential relationship in his statement that "organization shapes behavior."

If, as I hope, I have been successful in showing (1) that physiology has great potentialities for the further study of large biological and human problems and (2) that it has not so far lived up to its promise, I have two things yet to do. We may consider first the reason why physiology has not fulfilled its promises and then make some attempt at the general fulfillment of the promise given in the introduction, to consider man's reaction to the general conditions of the war. As to the reason why physiology has had such a limited development, compared to its opportunities, I suspect German academic influence in great part. The grounds for this suspicion are found in the following quotation from Merz:[26]

> I must remind the reader here that though I use the word biological as denoting the more recent point of view from which all phenomena of the living world are being grouped and comprehended, and though the word seems first to have been used by a German, nevertheless, the arrangement of studies at the German universities has hardly yet recognized the essential unity of all biological sciences. They are unfortunately still divided between the philosophical and the medical faculties. It is indeed an anomaly, hardly consistent with the philosophical and encyclopaedic character of German research, that palaeontology, botany, zoology and anthropology, should belong to the philosophical, whereas anatomy, physiology and pathology are placed in the medical faculty. Eminent biologists and anthropologists, such as Schleiden, Lotze, Helmholtz and Wundt, have accordingly belonged to both faculties. To place biological studies on the right footing would require a mind similar to that of F. A. Wolf, who evolved out of the vaguer idea of humaniora the clearer notion of a science of antiquity, and who accordingly was able to convert the training school of teachers, the seminary, into a nursery of students of antiquity. Whether a similar reform in the purely scientific interests of the "science of life" which is now mostly cultivated for the benefit of the medical practitioner, can be effected in this age when practical aims are gradually taking the place of scientific ideas, is another question.

When we remember the date when this was written (1903) it will be seen that it was not mere war hysteria, but the well-considered opinion of a scholar, arrived at after long and careful study of the problem. For this very reason, it commands more respect and attention than it otherwise might.

The condition which Merz describes does not exist in Germany alone. Physiology, as it has been developed in America,

[25] "Animal Behavior," Marine Biological Lectures, Woods Hole, Session of 1893, p. 298, Boston, 1899.

[26] Vol. 1, p. 220.

largely under the influence of the German schools as I believe, has not concerned itself much with the relation between organism and environment. With little exception, American physiology has been a strictly subordinate subject in a polytechnicum, concerned more with those phases of internal organization which have a supposed immediate medical interest than with those which have a more general scientific interest, and dealing more with those aspects of the relation of the organism to the environment which may be comprised within the limits of the pharmacist's stock of drugs and the appliances of the hospital and the sanitarium than with the relations of organism and environment as they exist in nature generally. The technical aspects of physiology must, of course, be investigated and taught. I am inclined to believe that they should occupy an even larger place in the medical curriculum than they now hold. But these technical aspects should by no means comprise all of physiology. Chemistry and physics long ago passed from the control of medical faculties and began their course of development as independent scientific subjects. It would be interesting to speculate upon their probable present stage of development if they had remained under the exclusive control of either medicine or engineering.

If any insist that there have been no agencies which have tended to retard the progress of physiology, we have still to explain why it has not fulfilled the promise of development which it had in the days of Claude Bernard and the French School of his time. The field has been mapped out and, if there have been no retarding influences, the only alternatives appear to be that a part of the field is unworthy of being worked, or that no men of sufficient vision have appeared to work in all parts of the field, neither of which appears to be wholly reasonable.

The more general phases of physiology are now for the most part being studied in departments of zoology, particularly by the animal ecologists, and botany. The students of the effects of the environment on the organism have been, for the most part, less familiar than they should be, with the details of the internal functional organization of plants and more particularly of animals. The students of internal organization have too often cared but little or not at all for the relation between changes in the environment and possible changes in internal organization. Without the cooperation of workers along each of these lines, and others as well, it does not seem possible that physiology should reach its maximum usefulness to science in

general, and, through science, to the human race. It will not reach its greatest development as a science until more universities establish departments of general physiology, or extend existing departments for the study of the relationships of organism and environment in their widest phases.

It would not, however, be strict justice to German physiology to say, either that all of the tendency toward the restriction of physiology to the narrower field was of German origin, or that no attempts to raise the wider aspects of the science to a plane equalling in popularity and influence that on which the narrower view rests. Verworn, Rosenthal and others, following the leadership of Claude Bernard's classic volume, have presented the subject of general physiology in meritorious texts, and a journal devoted exclusively to general physiology has been published in German for some years past. The relative prominence of the German publications has even led to the neglect of some of the French works on the same subject.

There are indications, however, that the strictly medical side of physiology as it has been taught is no longer quite adequate to the demands of the medicine of the future. Even medical men are beginning to look around beyond the present boundaries of the curriculum. An earlier statement of my own that the physiologist would seem to be the best qualified person finally to decide upon questions of adaptation, and a further statement that the theory of organic evlution seems the best place for workers in every line of biology to bring their results for the inspection and criticism of others, has recently received gratifying support from a medical source. In his volume on the relation of Medicine to Evolution, Adami[27] remarks, that "these matters of adaptation and evolution have of necessity to be approached from the aspect of function and the dynamics of living matter, rather than from the point of view of cell statics." Haldane[28] has considered the relation of the organism to the gaseous environment in detail.

If, as has already been indicated, evolution is one of the properties of living matter, it falls within the province of the physiologist, and its mechanism is to be explained, just as the mechanism of other physiological processes is to be explained, on the fundamental basis of changes of matter and energy. That the task is one of surpassing difficulty, few will doubt, and that we shall quickly arrive at a solution of the problems few

[27] "Medical Contributions to the Study of Evolution," New York, 1918, p. 85.

[28] "Organism and Environment as Illustrated by the Physiology of Breathing," New Haven, 1917.

will hope. The best we can do is to continue work along these lines.

In industrial life too, there is the beginning of an idea that the conditions of work in factories and offices may affect the amount of work done in a day. The human organism becomes a human machine in industrial plants, and it would seem axiomatic that the student of its internal organism should be the one best fitted to study its operation under industrial conditions.[29]

I may here summarize the field of biology, and especially that of physiology by quoting again from the distinguished Briton, Burdon-Sanderson:[30]

> From the short summary of the connection between different parts of our science you will see that biology naturally falls into three divisions, and these are even more sharply distinguished by their methods than by their subjects; namely, Physiology, of which the methods are entirely experimental; Morphology, the science which deals with the forms and structure of plants and animals, and of which it may be said that the body is anatomy, the soul, development; and finally, Oecology, which uses all the knowledge it can obtain from the other two, but chiefly rests on the exploration of the endless varied phenomena of animal and plant life as they manifest themselves under natural conditions. This last branch of biology—the science which concerns itself with the external relations of plants and animals to each other, and to the past and present conditions of their existence, is by far the most attractive. In it those qualities of mind which especially distinguish the naturalist find their highest exercises, and it represents more than any other branch of the subject what Treviranus termed the "Philosophy of living nature."

What is true of animals is true in greater or less measure of Man. We may now pass on to the consideration of man in his relation to his social and political environment.

(To be continued)

[29] Lee, F. S., "The Human Machine and Industrial Efficiency," New York, 1918, good bibliography.

[30] *Loc. cit.*, p. 465.

TWO SOUTHERN BOTANISTS AND THE CIVIL WAR

By NEIL E. STEVENS

BUREAU OF PLANT INDUSTRY

A SCIENTIST'S observations often can be best evaluated in the light of a knowledge of the man and the conditions under which he worked. The following notes regarding two eminent American mycologists will then be of interest to botanists; and, in view of the similarities between the times in which they lived and the present, may be of more general interest as showing something of the effect of the Civil War and reconstruction period on the science and the scientists of the south.

The source of the manuscript letters on which the present notes are based is the correspondence of the late Professor Edward Tuckerman, Jr., of Amherst, Mass., fortunately preserved almost complete and now the property of Professor Tuckerman's nephew, Judge E. T. Esty, of Worcester, Mass., who has courteously loaned them to the writer for examination and to whom the writer is much indebted. The correspondence, consisting of over eight hundred letters, dating from 1838 to 1873, is bound in nine quarto volumes and contains letters from practically all the American and many European botanists of that time.

The subjects of this sketch, the Rev. M. A. Curtis and H. W. Ravenel, were both distinguished for their contributions to botany, especially in the field of mycology. They were constant friends and co-laborers and apparently had a voluminous correspondence. At present only their letters to Tuckerman are available. Curtis was a native of Massachusetts, born in Stockbridge and graduated from Williams College. He went to Wilmington, North Carolina, at the age of twenty-two as tutor in the family of Governor Dudley. From this time almost continuously until his death he made his home in the Carolinas. As to his sympathies during the Civil War his correspondence gives not the slightest hint.

Ravenel, on the other hand, was of an old southern family, as he writes Tuckerman in a letter dated "Plantation near Black Oak [S. C.], March 23, 1857."

I have a peculiar love for this section of country—my native place, (here on this very plantation and house, the old family homestead, where I am now writing) and the home of my friends—Here, for six or eight generations, since our Hugenot fathers fled from persecution at the revocation of the Edict of Nantes, have the ties of home attachment been growing and strengthening. . . . The graves of our ancestors are here on these old family seats, and these sacred spots, which had their origin from the rude state of the frontier settlements have been kept up and used with pious care. They constitute, together with the traditionary history of their occupants, an endearing bond with the living, and tend to keep alive a sentiment of filial love and veneration.

It was here on these very plantations which their descendents still continue to occupy, that our ancestors cultivated rice and indigo long anterior to the Revolutionary War. Then, as the scenes of skirmishes and hostile meetings between the contending parties, during "the times that tried men's souls," they have become classic ground to the historian. It was here that the "Swamp Fox" Genl. Marion recruited his brigade, when nearly the whole state was in the hands of the British and tories—and in the wild fastnesses of the Santee swamp, formed a nucleus of hope to the desponding patriots.

It is not then surprising that it is from Ravenel, interested as he was in the history and traditions of his section that we hear the first suggestion of sectional difficulties. He closes a letter written, December 31, 1850, with the following paragraphs:

I have never entertained a doubt that a large portion of the intelligent and patriotic citizens of the North, whatever they may think of our domestic institutions, are disposed to be faithful to the compromises of the constitution and the rights of the States—Could the settlement of this distracting subject be left to them, I would have confidence in the issue—But I fear the decision of the question has passed beyond their power—Demagogueism and fanatacism have swept with demoniac fury over the land, and the voice of reason and patriotism is almost hushed.

The South has loved the Union for the common glories of the past, and for what might have been the common glorious destiny of the future—She has made, and would be willing to make great sacrifices for its preservation—But her honor and self-respect she cannot sacrifice. She has not so learned her lesson of liberty from the great fathers of the republic in the days of its purity—The future is dark and portentious—and I almost despair of the integrity of the Union, but it may be that he who has hitherto so signally blessed and prospered our country may overrule the wicked machination of its foes.

The differences in national opinion which led Ravenel to look upon the future as "dark and portentious" were of course those which arose from the question as to the basis on which California should be admitted to statehood. Difficulties which were temporarily settled by the legislation arising from Clay's historic "Omnibus Bill," a settlement which seems to have

been satisfactory to Ravenel at least, for during the next ten years we find no mention of such matters in his letters.

Letters frequently tell as much by what they omit as by what they include, and it is certainly not without significance that in the score of letters which passed from each of these southerners to their northern friend during the years from 1850 to 1860 there is no mention of political affairs. This is particularly true when it is remembered that this decade was marked by events which were perhaps the most portentious through which this country has passed. Within this time came the birth of the Republican party, with its anti-slavery platform, the disagreements over the enforcement of the fugitive slave law, John Brown's raid, and the bitter struggle for Kansas.

Apparently southern botanists were not interested in politics. Ravenel's last letter, written on October 29, 1859, deals, as had the previous ones, with specimens sent and collections made and with "the preparation of my fifth century of fungi," which he hopes to be able to issue "in the course of a few months." Curtis was even less distracted by events not botanical. Though he is disturbed by the failure of the federal government to give proper attention to mycological collections.[1]

> What a pity that Government does not employ Curators for the preservation and judicious distribution of its collections, instead of leaving them to be eaten by insects, or stolen by unprincipled visitors. There is a large mass of duplicates among the Fungi now in my hands. How are they ever to be distributed properly, without an officer employed for the purpose, and one who has some knowledge of such matters.

On July 16, 1860, he writes asking Tuckerman's help in preparing a complete list of plants for the state geological survey:

> I am preparing, in connection with our Geological Survey, a list of the Plants of this State. I desire to make it as accurate and complete as possible, and that end will be far nearer attained, if I can have your assistance. I send you a list of all the Lichens I know of, belonging to this State, about one-half, I suppose of the actual number. I presume you can add a good many. . . .
>
> My first Report (on the Woody Plants of N. Car.) in a small pamphlet, should be published about this time, and I have ordered a copy to you.

During September, 1860, on the eve of Lincoln's election, Curtis interviews the Governor of North Carolina on a subject far from political and writes his friend Tuckerman as follows:[2]

> Yesterday I had an interview with our Governor, and told him that I

[1] Letter dated March 10, 1859.

[2] Letter dated September 12, 1860.

had rather wait till the end of the current year before making another Report. As he assented to my humor, I can give you an opportunity of adding anything that may come to your notice between this and next December. So, please to consider your Report as *open* till that date for any additions or corrections.

Even later educational and scientific problems seems to have filled his mind, for in October he made a trip to Tennessee, the purpose of which he outlines in a letter dated "Oct. 23d, 1860."

You appear to have inferred that I went westward for "explorations." So far from this, I had no time for them at all, and collected not a solitary specimen except what I now enclose, which I hastily gathered en passant. My journeys westward for the last three or four years (in Aug. 1859 to Tenn; in Feb. last, to N. Orleans, and now again to Tenn.) are in connection with "The University of the South," of which I have been a Trustee from the beginning. The corner stone was laid on the 10th with much ceremony, and in the presence of about 5000 persons.

The closing days of 1860 find our botanists deeply engrossed in their favorite pursuits, Ravenel busy with the preparation of another volume of his Exsiccati and in collecting "likenesses of American and European Botanists"; Curtis at work perfecting his list of plants for the State Geological Survey and urging upon the governor their proper publication; and both all the while sending from the heart of the Carolinas to their friend Tuckerman in abolition Massachusetts, specimens of lichens, personal photographs, notes on plants collected and exchanged, together with delightfully intimate friendly letters full of good wishes and encouragement, and congratulation on his published work.

Here follow five years of silence, broken so far as this correspondence is concerned by only a single southern letter,[3] which is of interest as bringing out the condition of science in the south during the war.

Since the war I have very much fallen behind a respectable knowledge of scientific progress in your department. Scientific pursuits are pretty much suspended in the South now—Minerva, Apollo and the peaceful Deities are driven from our Camps and only Mars remains.

Southern opinions and Southern purposes you will learn from our Newspapers—they do no credit to your Courage or your Conduct. What the result will be, God only knows; but I fear that it will be only the destruction of the best Government in the world and the substitution of the Jiff Davis Dynasty in its stead. Mr. Lincoln's management is wretchedly stupid and inefficient and will end badly, I fear.

The letter just quoted was written March 15, 1863, more

[3] This letter was written to Tuckerman by Thos. Peters, a lawyer and amateur botanist of Moulton, Alabama. He was a friend and correspondent of Curtis, Ravenel, and Tuckerman.

than three months before the battle of Gettysburg. It is probable that Peters's attitude reflects that of many observers, both north and south, as to the probable success of the Confederacy.

Grant and Lee met at Appomattox on April 9, 1865. On August 26, 1865, Ravenel wrote his friend Tuckerman what he characterizes as "the first note written beyond our lines."

The bloody drama is over—and the four years of carnage is completed! The curtain now rises upon a new scene. What has occurred during these years that we have been shut out from the outside world? Are my old friends with whom I used to converse so agreeably in former times, still in their accustomed place and occupation, or have changes occurred? These and other questions of like import, have made me feel anxious to hear once more from you and others of my former correspondence. Mail communication is now partially resumed, (at least sufficiently so to send a letter through Charleston) and I indite this my first note written beyond our lines to my friend Tuckerman.

Plurimam do Salutem. We are no longer enemies by law, and I send you my greetings.

I cannot know, nor do I ask what your opinions and predelictions have been during the continuance of this bloody struggle. It is over—and its records are made. It has pleased the great Umpire of nations in the order of his Providence, that the Southern Confederacy should not accomplish the object for which they sought. So be it. I accept the issue as from His hands—and am content.

This attitude on Ravenel's part should by no means be taken to indicate that he had not suffered from the war or that he was not a thorough partisan; farther on in the same letter he writes:

All my sympathies have been for our success. I believed the time had come when our country, overgrown in territory (as I supposed) and with discordant and conflicting interests, would best accomplish its destiny under two separate and independent governments. It has been otherwise ordered by the Great Ruler of nations. I submit without discontent, because I know that infinite wisdom cannot err. I accept the verdict rendered, and in good faith intend to do all that the duties and obligations of a good citizen may require.

. . . .

I have lost all my property, and must henceforth seek some employment for the support of my family.

. . . .

The deplorable state of affairs can scarcely be appreciated. Accustomed as we have been in this new country to abundance of the necessaries of life, we had come to think of destitution and famine as evils only belonging to the old world. The reality has been brought home to us—and many a family who lived in affluence, now scarcely knows from day to day, the means of living.

His poverty was real, for he plans to sell his farm, his books, even his herbarium, and asks Tuckerman to help find a pur-

chaser, but even more eloquently than his words do the poor quality of the paper and especially of the ink which he uses in these letters bespeak the poverty of the man and of his section. The war had evidently forced his favorite pursuit from his attention, and his concluding paragraph contains the remark,

> I have done nothing during the war in Botany. Other matters were too absorbing.

War influenced Curtis's studies also, for his first letter to Tuckerman concluded with this paragraph:

> During the late war I paid no attention to Botany, except to the edible Mushrooms, from which I have gotten many a substantial and luxurious meal. My experience in this way, and that of several families about me to whom I imparted the knowledge I had acquired, have induced the belief that I might serve the public by a publication of what I know on the subject. Should I succeed in finding a Publisher, I shall be happy to send you a copy.

Evidently botanists have always done their bit in the case of a food shortage.

Reconstruction days were not favorable for the publication of scientific matter. On February 5, 1866, he writes:

> My "Mycophagia Americana" hangs fire for the present on account of the enormous cost of publication. Prof. Gray has the thing in hand, and thinks prices will fall after a while, and that I shall have to wait. I have been ready with material these four or five months.
>
> . . . .
>
> P. S. Some five years ago you were kind enough to arrange a list of N. Carolina Lichens for me towards a complete list of the Plants of this State. The war broke out soon after, and the printing of my Reports on the Nat. Hist. of N. Car: was suspended. When it will be resumed I know not. In our present poverty, and with our enormous taxes, I doubt if our present Legislature will give any attention to so insignificant a matter, though I have addressed the Governor on the subject. If it is ever printed, and I mean that it shall be, you shall have a copy of course.

Imagine the feelings of the Governor of North Carolina during the first days of reconstruction being urged to publish a list of plants! The matter is referred to the state legislature which takes the action on this matter of publication that might be expected and a few weeks later Curtis reports:[4]

> Since my last, I have recd. a communication from a Committee of our Legislature, proposing that I should publish my Catalogue of N. C. Plants, and a new edition of the "Woody Plants of N. C." on my own account. Our poverty and heavy taxes make the Legislature very chary about burdening the State with even the small amount of such publications. I prefer that the State should do the work; but if it will not, I believe I will run the risk of some loss upon the Catalogue which I am very anxious to have in print.

[4] Letter dated Feb. 22/66.

It is pleasant to be able to record that this list of plants was finally published by the state (1867).

Ravenel's letters from 1866 until the correspondence closes are a record of struggle against the dangers and difficulties of the reconstruction period, the unaccustomed task of earning a living for his family, and most depressing of all a struggle against ill health. On November 8, 1865, he writes:

With respect to my collections nothing but a sense of necessity would induce me to part with them. I have half relented already in my intentions of selling, and hope the necessity may not arise. We suffered much during the war from privations of all kinds, and especially towards its close—but we endured these hardships, cheerfully hoping for honorable peace to come in time. At its close we found ourselves suddenly brought to poverty,—and our hopes destroyed by its termination so different from what was expected—Still our people were satisfied to accept the issue, and in good faith to abide by the decision against us. We took the oath of allegiance and were prepared to do our duty and fulfill all our obligations as good citizens. It was during the two or three months succeeding the surrender of our army, that the southern people were compelled to pass through the most trying ordeal and to drink the bitter cup of humiliation to its dregs. The military leaders offered us terms which were honorable and which were accepted in good faith. We were prepared to renew our allegiance, and accept the terms which had been offered with the best intentions of forgetting the past and healing old animosities. The terms were repudiated by the civil authorities and we were subjected to military government of the most odious kind. Troops of black savages with arms in their hands were quartered in every town and village, to maltreat and insult us, and to stir up the slaves to revolt and insurrection. Wherever these black troops were sent, they created disaffection among the negroes, and incited them to leave their homes—thus causing vagabondism, idleness, and mischief. They had not been here 12 hours before they had a riot at one of our churches on the Sabbath during prayer hours, the day after that they entered a widow lady's house to insult and abuse her, and on her son's going to headquarters to report the fact, he was knocked down and nearly murdered in hearing of their officers. Ladies were abused and cursed in the streets, and no redress (sufficient to stop such conduct) could be obtained. There was real danger for a while of the negroes being stirred up to acts of bloodshed and murder. These and other atrocities we were compelled to bear without the means of redress and apparently without hope of amelioration. It was then that I wished to leave the country and go anywhere, where law and order prevailed. I am glad to say that a much better state of things now prevails. The military authorities have removed the black troops, and the negroes are quiet and orderly.

And again in March, 1866, he exclaims:

We are charged with disloyal feelings and with a desire to oppress the freedmen unless restrained. There is positively no truth in either of these charges. Our people have with most wonderful unanimity, accepted the issues of the war as final and irreversible. They struggled manfully for four years and put forth their entire strength and resources in the fight,

because they conscientiously believed they were battling in the cause of Civil Liberty for a great principle, the right of Self Government. The fortunes of war have been decided against them. They failed after all their efforts for independence, and now as a law-abiding people who have been trained in the school of constitutional government, they are willing to abide by the issue in good faith and give their allegiance to the govt which protects them and under which they are to live. I am sure that 99 per cent of our people hold these views. That there still continues to exist in some quarters, ill feelings toward the Govt.—that the sense of injuries and of suffering should still linger in some breasts—that is only what we might expect. It would be miraculous, were it otherwise, so long as human nature remains as it is. But with the great mass of the people, these feelings do not exist—and their existence in the few can do no harm. They will gradually disappear under the healing influence of time. A great nation victorious and triumphant everywhere, without a solitary foe to dispute her power, may well exercise clemency in dealing with the harmless vagaries of a few discontented spirits.

Yet such is his friendship for Tuckerman that he is able to write in the same letter:

Your last letter received some time ago, gave me much pleasure. I have not replied sooner simply because there was nothing especially to call for a reply except to tell you how highly I appreciate the kind feelings evinced towards me personally—and the very liberal and Christian spirit in which you regard the late national chastisements.

During 1867 there are no letters, but on January 12, 1868, he "interrupts the silence" with "A New Year's Greeting" and adds:

I would like to hear once more from you. Your letters are always welcome, instructive and interesting. They remind me of the times when I was more engaged in botany than I am now, or can ever hope to be again. I have now at least the satisfaction of these pleasant reminiscences, and the hope that my labors may have contributed somewhat to botanical science. What have you accomplished in the year passed? And what progress is made in your work on N. Am. Lichens. I suppose your Exsiccati is not yet out or I should have heard from you.

Please give me a line and tell me of your labors. I am still interested in botany though I can very little afford any time for its pursuit. It is now a struggle for subsistence.

During the next month he refers more at length to his poverty and that of his section. (Letter dated Feb. 21st, 1868.)

You say "you trust I am not weaned from botany." I still linger on the outskirts (as it were)—but am compelled from necessity to do whatever comes to my hand, to get my daily bread. I suppose you can form but a faint idea of the universal destitution prevailing throughout the Southern States. All are in poverty. . . . No capital will venture here while this state of things continues—and there is nothing left to our own people to begin the work of rebuilding their broken fortunes. . . . I feel like a shipwrecked mariner who has been cast upon a desert coast, and forced

to subsist on whatever may be washed ashore and on the crude sustenance to be found at hand. . . . I once had a sufficiency to follow my inclinations, and *avoid* the tracks of trade. . . . I get a comfortable living (by using great economy) in selling vegetables from my garden and doing a little wood cutting for the railroad, disposing of such books as I can best spare and occasionally selling one of my botanical collections (those collected for the purpose of sale.) I have not touched my herbarium and intend to hold on to that. . . . Do not understand me as murmuring, or complaining of my lot. It is only that of thousands of others. Indeed I have daily cause of thankfulness to a kind Providence which has so signally blessed me. With my large family (10) in number) to provide for, I cannot avoid at times feeling anxiety. . . . Excuse me for dwelling too much upon matters which are painful to hear of. They occupy so much of my thoughts that they find expression but too readily. I always train myself to look at the cheerful side,—and am still in hopes that the dark clouds that overhang us, will soon pass away. At any rate, we *know* that the sun still shines beyond, and that in good time its genial rays will enliven and bless our land.

Scattered letters through 1869 mention a continued interest and, so far as circumstances permitted, activity in the botanical field. During the early months of 1870 he seems to have rendered Tuckerman considerable assistance by sending specimens of southern lichens, but under what difficulties is shown by two letters written during March.[5]

I have been occupying myself lately in making up sets of Lichens which I shall dispose of. I am under the necessity of doing this or else abandoning Botany altogether and seeking some other occupation that will give me a living.

You must excuse me if I send you the same things over under different names,—and some of which ought to be familiar to me. I have scarcely opened my Vol. of Lichens in the last 12 or 15 years,—and this last sad decade has mostly driven my thoughts from botany. And moreover I have parted with my microscope, and though I have the use of it whenever I want, I find the powers are not high enough for a satisfactory examination—(the smaller lens being *worn out*) and there are so many of the new species not yet described that I am often perplexed how to decide. . . . In making up my sets for sale, I think two good objects may be accomplished—one to furnish me with a little addition to my scanty means—and the other to enable those who are interested in the study to obtain our Southern Lichens.

Throughout the difficult years following the war, his love of botanical study and his friendship for Tuckerman seems to have remained among Ravenel's chief pleasures. His last important letter to Tuckerman (written May 3, 1870) concludes with the following paragraph:

My chief converse and entertainment is with my correspondents, who like yourself and one or two others, have been rambling the same pathway

[5] Letters dated March 2 and March 22, 1870.

of life for now a quarter of a century. To me, the reminiscences of these earlier pursuits are exceedingly pleasant,—and a long and uninterrupted friendly intercourse, give additional strength to the bonds of a friendship established on common pursuits and sympathies. These are the things which make the retrospect of life grateful to us—and nerve us to higher aims and objects.—The asperities of political strife trouble me but little. I try to live in an atmosphere above them and to look on all these movements as the trickery of the political.

The scientists of to-day face a reconstruction period in international affairs perhaps no less trying than were those of 1865 to '70 in national affairs. It is possible that now as in '65 "the first note written beyond our lines" will come from scientists recently counted as "enemy," but who before the war were in close touch with this country. And it is to be expected that American answers will be such that correspondents will with Ravenel "appreciate the kind feelings evinced toward them personally,—and the very liberal spirit" in which we regard the late international chastisements.

WILLIAM RAMSAY

By BENJAMIN HARROW, Ph.D.

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IN that elegant tribute to Ramsay, written in the days when comradeship between the scientists of England and Germany was close, Ostwald summarizes him as one belonging to the romantic type in science. Romantic he was, for his imagination was unlimited. The secret of Ramsay's great triumphs lay in the fact that with this imagination there was a well-balanced knowledge of the science, with a seer's insight into the significance of its laws. Bold in the conception of a problem, he was brilliant beyond comparison in its execution. With no fetish to hold him, with the mantle of the prophet about him, and with amazing manipulative skill, he laid bare, in rapid succession, a regular little battalion of new gases in the atmosphere, followed by transmutation experiments which made the scientific world gasp and hold its breath in expectancy of the next dare-devil leap.

This genius, born in Glasgow in 1852, did not spring from any geniuses, but, like many another man of talent, his stock was of a fairly ordinary type. To be sure, there was an uncle with a reputation as a geologist, and the father had some scientific tastes, but nothing at all to warrant such outpourings in the offspring. When eleven years old he joined the Third Latin Class of the Glasgow Academy, and during the three succeeding years at the institution he did little Latin, gained no prizes, and did much dreaming. Ramsay describes himself in a short autobiography as "to a certain extent precocious, though idle and dreamy youngster." This fits in with Ostwald's theory of the genius: "The precociousness is a practically universal phenomenon of incipient genius, and the dreamy quality indicates that original production of thought which lies at the basis of all creative activity." Even thus early he evinced a passion for languages, for it is recorded that during sermon time at church he read the French and German texts of the Bible and translated them into English. In after years, as president of an international scientific gathering, he would astound the assembly by addressing them successively in French, German and Italian.

His introduction to chemistry came in quite an unexpected way. A football skirmish resulted in his breaking a leg, and to lessen the monotony of convalescence, Ramsay read Graham's "Chemistry," with the object, as he frankly confesses, of learning how to make fireworks. During the next four years his bedroom was full of bottles and test-tubes, and often full of strange odors and of startling noises. But systematic chemistry was not taken up till 1869, three years after he had entered the University of Glasgow. Then, it seems, the passion came on, and with it, a passion for the cognate science, physics. This resulted in an introduction to William Thompson (later Lord Kelvin), the then professor, who set the youngster upon the elevating task of getting the "kinks" out of a bundle of copper wire, an operation which lasted a week. It is to be presumed that Thompson was favorably impressed with the manner in which this piece of research was carried out, for Ramsay was immediately introduced to a quadrant electrometer and asked to study its construction and use.

A year's introductory study of chemistry decided Ramsay upon his career, and with his parents' blessing he set out for Heidelberg in 1870, to be exchanged for Tübingen some months later. In Tübingen ruled Fittig, whose lectures were "distinct and clear," whose scholarship was sound, and whose research was methodical. The two years spent at Tübingen were full of work and no play. "I was up this morning," he writes to his father "at 5.30 and studied and took my breakfast from 6 to 7,—a class from 7 to 8, one from 8 to 9, and 9 to 3 laboratory (I lunch now to have more time for work, and don't dine till 6), and from 3 to 5 I studied, then from 5 to 6 lecture, and then I dined. And now at 8 I must start again." And so this was kept up—all the time, curiously enough, with emphasis on organic chemistry, a branch of the science which Ramsay almost wholly abandoned in his later and most productive years—till the time for the Ph.D. examination. "On Monday at 7 it began and lasted till half-past 12; then in the afternoon from 3 to 8, so we had a good spell of it." The questions in chemistry were: (*a*) the resemblances and differences between the compounds of carbon and silicon, and (*b*) the relation between glycerine and its newer derivatives and the other compounds containing three atoms of carbon; in physics: (*a*) the different methods for determining the specific gravity of gases and vapors, and (*b*) the phenomena which may be observed in crystals in polarized light.

I managed to answer the first perfectly, the second, however, not so well, and the two questions in physics pretty well. Then to-night we had the oral exam. The five professors who compose the faculty were there. Fittig gave some very difficult questions. Reusch (physics), on the other hand, very easy ones. . . . We had to dress up and put on white kids, and I had to get a "tile" especially for the occasion. Then we were sent out after the exam. for about five minutes and were then called in and formally told we had passed.

A dissertation on "toluic and nitrotoluic acids," which gave no glimpse of the future before him, completed Ramsay's Ph.D. requirements, and he returned to Glasgow, where he became assistant in the Young Laboratory of Technical Chemistry. And now Ramsay had to turn his attention from organic to inorganic chemistry, for most of the courses at the technical school were devoted to the latter. Though the physico-chemistry background was entirely lacking, and therefore the knowledge obtained could hardly have been more than miscellaneous, innumerable facts were picked up and stored for future reference. An opening as tutorial assistant at Glasgow University offered the possibilities of a more congenial academic atmosphere, and also the hope of continuing his interrupted research in organic chemistry.

The cellars of the University Laboratory contained a large collection of fractions of "Dippel-Oil" prepared by Professor Thomas Anderson. These were regarded by Ferguson (his successor), whose interest in Chemistry was almost entirely that of an antiquary, more or less in the light of museum specimens, and he was horrified when Ramsay suggested that he should be allowed to "investigate" them, but he eventually gave way to Ramsay's importunity. The result was a very substantial addition to our knowledge of the pyridine bases and their derivatives.[2]

The chemistry of dyes and explosives was not to be his life work. How he turned from this to the more mathematical branch of the subject is ascribed by Ramsay himself to problems he encountered in attempts to determine the molecular weights of some of his organic compounds by the Victor Meyer vapor density method. But we must also add that Ramsay, with that instinct for detecting the truly important among a mass of new theories and facts, which was one of his greatest assets, early foresaw the part the new science of physical chemistry would play in the development of chemistry. Thus he was one of the earliest in England to appreciate the true significance of Guldberg and Waage's "law of mass action," just as, at a later date, he was among the first to seize upon and translate Van't Hoff's celebrated paper on the analogy between

[2] "Sir James Dobbie" (68), p. 48.

the state of substance in solution and the same when in a state of gas. The Victor Meyer method suggested to him experiments on the volume of liquids at their boiling point, and this in turn gave rise to a whole series of new possibilities, the experimental side of which kept him and his collaborators, particularly Young and Shields, busy even after he had settled in University College years later.[3]

For six years Ramsay remained assistant at Glasgow University, and though during that time he had been a candidate for several chairs and lectureships, nothing came of any of them. So discouraged did he become that there was much discussion in the family as to the advisability of starting business as a chemical manufacturer. But before this scheme could be put into execution a vacancy at University College, Bristol, presented itself. The story goes that his knowledge of Dutch saved the day. According to this account one of the members of the university council, a minister, was much perplexed with a Dutch text in his possession, and Ramsay volunteered a translation. The result was Ramsay's appointment by a majority of one. The stipend was fixed at a minimum of £400 ($2,000) per year. The contract read:

> The professor will be required to give three lectures per week for the first two terms, say 60 lectures, together with class instruction in connection therewith . . . and a short course of lectures in the third term. He will also be required to superintend the laboratory during the whole session, and to give evening lectures once a week during the first two terms, together with class instruction in connection therewith. . . . The scheme of the college contemplates the possibility of occasional lectures being delivered in neighboring towns by the Professor or his assistant. . . . In connection with the Cloth working Industry, special instruction in dyeing, etc., may be required under an arrangement not yet concluded with the worshipful the Cloth-workers' Company of London.

The professor, not yet turned thirty, was to be kept busy on the job, with very little opportunity for research—an altogether minor consideration to the worthy councillors. But they had not reckoned on Ramsay's energy and capacity. Determinations of the density of gases, of the specific volumes of liquids at their boiling point, of the vapor pressures and critical constants of liquids were soon in full blast. And then came those

[3] It was while blowing the bulbs used in this research (the volumes of liquids at their boiling point), I believe, that he first became aware of the asset he possessed for physical work in his skill as a glass-blower. He had learnt the art at Tübingen, although it was only in his later researches that his marvellous manipulative power was fully developed.—Sir James Dcbbie.

classical determinations on the thermal properties of solids and liquids, and on evaporation and dissociation, most of which was done with his assistant, Young, which continued at full blast for the next five years until Ramsay's transfer to London. This appointment came in 1887. By that time Ramsay's reputation was such that the following year he was elected an F.R.S. (Fellow of the Royal Society).

In London his physico-chemical researches were further extended. Among these particular mention should be made of perhaps the most brilliant of them all—the measurement of surface tension up to the critical temperature, which led to the well-known law supplying us with a method for determining the molecular weight of liquids. Here Ramsay had an able assistant in Shields.

In 1890 the British Association met at Leeds, and two of the great continental founders of modern physical chemistry, Van't Hoff and Ostwald, were present. Ramsay, who represented the school in England, naturally took a keen interest in this meeting.

> Ramsay and Ostwald met for the first time as fellow-guests in my house, which became accordingly a sort of cyclonic center of the polemical storm that raged during the whole week. . . . The discussion was incessant. . . . I remember conducting a party to Fountains Abbey on the Saturday and hearing nothing but talk of the ionic theory amid the beauties of Studley Royal. The climax, however, was reached the next day, Sunday. The discussion began at luncheon when Fitzgerald raised the question of the molecular integrity of the salt in the soup and walked round the table with a diagram to confound Van't Hoff and Ostwald. . . . Ramsay was no silent spectator. Being a convinced ionist, he was eager in helping out the expositions of Ostwald, whose English at that time was imperfect and explosive, and his wit and humor played over the whole proceedings. . . . It was the beginning of relations of great mutual sympathy and regard between Ramsay and Ostwald, which lasted till they were divided by their respective national sympathies at the unhappy outbreak of war.[4]

And now we come to a momentous event in the career of our hero. Lord Raleigh had for some time been engaged in determinations of the exact densities of a number of gases. Among these was nitrogen. In his experiments Raleigh found that the density of nitrogen obtained from the air was slightly but consistently higher than that obtained from artificial sources. Writing to *Nature* (1892) he says:

> I am much puzzled by some results as to the density of nitrogen and shall be obliged if any of your chemical readers can offer suggestions as

[4] Professor Smithells.

to the cause. According to two methods of preparation I obtain quite distinct values. The relative difference, amounting to about 1/1,000th part, is small in itself; but it lies entirely outside the errors of experiment.

The difference in the weights of one liter of the gas obtained in the one case from atmospheric air and in the other from ammonia varied by about 6 in 1,200, or about 0.5 per cent., but the accuracy of the method did not involve an error of more than 0.02 per cent.

With that keen scent for any promising material Ramsay immediately took up the problem. Some years previously he had found that nitrogen is absorbed fairly readily by magnesium. This suggested to him that by first getting rid of the oxygen in the air, and passing the remaining nitrogen repeatedly over heated magnesium, any other gas that might possibly be present in the atmosphere would remain unabsorbed. This unabsorbed gas was isolated and found to give a characteristic spectrum. The name *argon* was given to the newly discovered ingredient of the atmosphere. It proved to be more refractory than the comparatively inert nitrogen: it just simply would not make friends and combine with any other element!

Shortly after this Ramsay's attention was called to some experiments of Hillebrand, of the U. S. Geological Survey, in which he obtained a gas believed to be nitrogen from certain minerals, particularly one called clevite, but which was now suspected to contain argon as well. Ramsay lost no time. From it he obtained argon, to be sure, but also another gas, with a spectrum all its own, which showed it to be identical with an element present in the chromosphere of the sun, and which until then had been considered peculiar to the sun. Lockyer years ago gave the name "helium" to it, and now Ramsay had rediscovered it on mother earth. But let the discoverer tell the exciting news. On the 24th of March, 1895, he writes to his wife:[5]

Let's take the biggest piece of news first. I bottled the new gas in a vacuum tube, and arranged so that I could see its spectrum and that of argon in the same spectroscope at the same time. There is argon in the gas; but there was a magnificent yellow line, brilliantly bright, not coin-

[5] Ramsay married Margaret, daughter of George Stevenson Buchanan, in August, 1881, soon after he had been appointed principal of Bristol College—a position he attained one year after his arrival in Bristol. This union proved a particularly happy one. "To have such a helpmate as my wife has brought me happiness which I must acknowledge with the greatest thankfulness." And at a later date he wrote to a friend: "You have got a good son and daughter and that is much to rejoice at. So have I."

cident with but very close to the sodium yellow line. I was puzzled, but began to smell a rat. I told Crookes,[6] and on Saturday morning when Harley, Shields,[7] and I were looking at the spectrum in the dark room a telegram came from Crookes. He had sent a copy here[8] and I enclose that copy. You may wonder what it means. Helium is the name given to a line in the solar spectrum, known to belong to an element, but that element has hitherto been unknown on earth. . . . It is quite overwhelming and beats argon. I telegraphed to Berthelot[9] at once yesterday—"Gaz obtenu par moi clevite mélange argon helium. Crookes identifie spectre. Faites communication Académie lundi.—Ramsay." . . . I have written Lord Rayleigh and I'll send a note to the R.S. (Royal Society) to-morrow. . . .

The first public account of helium was given to a semi-bewildered audience at the annual meeting of the Chemical Society, 1895, on the occasion of the presentation of the Faraday medal to Lord Raleigh. Further investigations proved that helium was not only a terrestrial element, but also occurred in quite a number of minerals and mineral waters. To Kayser, however, was left the proof of its presence in the air. Like argon it simply refused to combine with any other substance.

To the ancients air was a source of investigation, and it had remained so. Till 1894 no one, least of all a scientist,[10] would have suspected the existence in the atmosphere of undiscovered elements. Ramsay and Raleigh's discovery shook the scientific world. Recognition came from all parts. Lord Kelvin, as president of the Royal Society, presented Ramsay with the Davy Medal, with the following comment:

. . . The researches on which the award of the Davy Medal to Professor Ramsay is chiefly founded are, firstly, those which he has carried on, in conjunction with Lord Raleigh, in the investigation of the properties of argon, and in the discovery of unproved and rapid methods of getting it from the atmosphere; and secondly, the discovery in certain rare minerals, of a new elementary gas which appears to be identical with the hitherto hypothetical solar element, to which Mr. Lockyer many years ago gave the name of "helium." . . . The conferring of the Davy Medal on Professor Ramsay is a crowning act of recognition of his work on argon and helium which has already been recognised as worthy of honor by scientific societies in other countries. For his discoveries of these gases he has already been awarded the Foreign Membership of the Société Philosophique de Genève and of the Leyden Philosophical Society. He has had the Barnard Medal of Columbia College awarded to him by the American Academy of Sciences, and within the last few weeks he has been elected a Foreign Correspondent of the French Académie des Sciences.

[6] Sir William Crookes, the famous physicist.

[7] His two assistants.

[8] 12 Arundel Gardens, their home.

[9] A famous French chemist.

[10] Cavendish, in 1785, did suspect some such possibility.

Such was the excitement aroused by these discoveries that even young students were filled with the epidemic. We are told that "answers to examination questions showed that oxygen as a constituent of our air was almost forgotten in the anxiety on the part of the candidate to show that he or she knew all about argon." But Ramsay had not yet sufficiently dumfounded his scientific confrères. From a careful study of Mendeleeff's periodic grouping of the elements he came to the conclusion that another inert gas ought to exist between helium and argon, employing a process of reasoning quite analogous to one used by the celebrated Russian many years before when, with the help of his periodic table, he predicted the discovery of new elements. Ramsay ransacked every possible source for this new element: minerals from all parts of the globe, mineral waters from Britain, France and Iceland; meteorites from interstellar space—all without result. A clue was at length obtained when he found that by diffusion argon could be separated into a lighter and heavier portion. This suggested the presence of the unknown gas as an impurity in argon. It was evident that the unknown gas, if present, could be there in minute quantities only to have escaped detection. That meant that the larger the quantity of argon employed the better the possibilities of getting appreciable quantities of the unknown constituent.

A simple method of separating the constituents in a mixture of liquids is to boil the mixture, and collect fractions of the condensed vapor. Each constituent will usually go off at a fairly definite temperature. This, in principle, was the method employed by Ramsay and his assistant, Travers. They prepared, to begin with, no less than fifteen liters of *liquid* argon!

> On distilling liquid argon, the first portions of the gas to boil off were found to be lighter than argon; and on allowing the liquid air to boil off slowly, heavier gases came off at last. It was easy to recognise these gases by help of the spectroscope, for the light gas, to which we gave the name *neon* or "the new one," when electrically excited emits a brilliant flame colored light; and one of the heavy gases, which we called *Krypton* or "the hidden one," is characterised by two brilliant lines, one in the yellow and one in the green part of the spectrum. The third gas, named *xenon* or "the stranger" gives out a greenish-blue light, and is remarkable for a very complex spectrum in which blue lines are conspicuous.

A trio, neon, xenon, krypton, added to helium and argon—making five new gases—and all in the atmosphere!

Further recognition came from the Chemical Society of London. They awarded Ramsay the Longstaff medal, given

triennially to the Fellow of the Chemical Society who, in the opinion of the Council, has done the most to promote chemical science by research. "If I may say a word of disparagement," added Mr. Vernon Harcourt, the president, in presenting the medal, "it is,"—and here we can see the twinkle in his eye—"that these elements (argon, helium, etc.) are hardly worthy of the position in which they are placed. If other elements were of the same unsociable character chemistry would not exist."

Ramsay's studies on helium led him to ponder over this question: why is helium only found in minerals which contain uranium and thorium—substances which give rise to radio-active phenomena? Attempts to answer this led him into the field of radio-activity, with results which even surpassed his investigations on the inert gases of the atmosphere. In 1903, in conjunction with Soddy, he succeeded in proving that helium, an element, could be produced from radium, another element. The transmutation of the elements come to life again! Those poor, foolish old alchemists, we were always led to believe, wasted their lives in vain attempts to transmute the baser metals into gold. And here comes the dashing Ramsay, bold, as usual, to audacity, and calmly announces that *his* experiments prove the alchemists not to have been such fools after all! Succeeding experiments on the action of radium salts on copper and lead solutions led Ramsay to believe that copper and lead can undergo disintegration into sodium and lithium, respectively—two entirely different elements! These latter claims still wait to be verified, but there is reasonable hope for assuming that various experimenters throughout the world will soon undertake the task of carefully repeating the entire work, now that peace is once again with us.

A fitting award for these achievements was the bestowal of the Nobel Prize to Ramsay in 1904. The distribution of the prizes took place in Stockholm on December 10 of that year, in the presence of King Oscar and the royal family, foreign ministers and members of the cabinet, and many leading representatives of science, art and literature. After speeches had been delivered by the vice-president and other representatives of the Nobel Committee, and of the academies of science, medicine and literature, King Oscar personally presented Lord Rayleigh (prize winner in physics), Sir William Ramsay[11] (chemistry) and Professor Pavlov (physiology) with their prizes, together

[11] Ramsay had been created a Knight Commander of the Bath (K.C.B.) in 1902, which carried with it the title of "Sir."

with diplomas and gold medals.[12] The distribution of the prizes was followed by a banquet, at which the Crown Prince presided. Count Morner proposed the health of Professor Pavloff, Professor Petterson that of Sir William Ramsay, and Professor Hasselberg that of Lord Rayleigh. The following day Ramsay delivered a lecture on argon and helium at the Academy of Sciences, which was followed by a dinner given in his honor by King Oscar. Writing from Switzerland to a friend some weeks later Ramsay says:

> We had a most gorgeous time for nearly a week, dining with all the celebrities, including old King Oscar. The old gentleman was very kindly and took Lord R. and me into his private room and showed us all his curiosities, the portraits of his sons when they were children and his reliques of Gustavus Adolphus and of Charles XII. The Crown Prince told Mag (his wife) that it was a difficult job to be a king, thereby confirming the Swan of Avon. He said that whatever one supposed a Norwegian would do he invariably did the opposite. Indeed there was nearly a bloodless revolution while we were there; the Prime Minister of Norway was there and I believe the dilemma was only postponed.

Ramsay remained at University College until 1912, when he retired. Two years prior to this, in conjunction with Dr. Gray, he determined the density of the emanation obtained from radium (which Ramsay named "niton") involving the mastery of experimental detail which established him once for all as the great wizard of the laboratory. The total volume of the gas under examination was not much beyond 1/10 cubic millimeter—a bubble which can scarcely be seen. To weigh this amount at all accurately required a balance turning with a load not greater than 1/100,000 milligram. When war broke out Ramsay placed his services at the disposal of the government. Much he could not do. In July, 1915, he writes to a friend that he had had several huge polypi extracted from his left nostril. "I have stood them for years, one gets into the habit of bearing discomforts, but it is a great relief." The relief was to be only temporary. Another operation became necessary in November.

> I was in the surgeon's hands on November 10th and again on the 13th, and he did an operation on my left antrum for a tumor, I believe very successfully. Since then, last Monday, I was irradiated for 24 hrs. with X-rays as a precaution against recurrence. Luckily it is of the kind which can be stopped by Radium. I have had a very bad time.

He died on July 23, 1916. He had lived not a long life but a very fruitful one and a very happy one. Writing to Presi-

[12] The sum of money attached to each prize amounts to about $40,000.

dent Ira Remsen, of Johns Hopkins, a few months before his death Ramsay concludes his letter with:

Well, I am tired, and must stop. I look back on my long friendship with you[13] as a very happy episode in a very happy life; for my life has been a very happy one.

Ramsay was many-sided. He was an excellent example of the very opposite of Punch's dry-as-dust philosopher. Among musicians[14] and among artists[15] he held his own, for he was an accomplished amateur in both fields. As a linguist he probably has had few equals among scientists. And those of us who, as late as 1912, heard him move a vote of thanks to Professor Gabriel Bertrand, of the Sorbonne, after the latter's lecture to the members of the International Congress of Chemists, will have formed a pretty good picture of his charm and ability as a speaker. Of the many letters that have been preserved, perhaps none sums up so well the characteristics of Ramsay as the following, written to his friend, Dr. Dobbie:

LE HAVRE,
Monday, the Something or other August, 1877.

My dear Dobbie,

Some fool of a Frenchman has stolen all the paper belonging to the French Association, and has left only this half sheet with Le Havre at the top. From the preceding sentence you will have already guessed that the French Ass. is capering around Havre at present, that I form one of the distinguished foreign members, and that all is going as merrily as a marriage bell. Voici 5 jours that I find myself here. I went to Paris with three spirits more wicked than myself, lawyers—a fearful compound 3 lawyers and a chemist—just like NCl_3 for all the world, liable to explode at any moment. . . . I have made the acquaintance with a whole lot of chemists, Dutch and French, and have found an old Dutchman named Gunning ravished to find someone who shares his ideas about *matter*, chemical combination, etc. We excurted yesterday the whole day and talked French and German alternately all the time. When we wanted to be particularly distinct French was all the go. For energy and strong denunciation German came of use. You can't say "Potz-teufel!" in French or "Donnerwetter potztausend sacramento!" An old cove, also a Dutchman, DeVrij, with bowly legs and a visage like this (sketch profile) is also a very nice old boy. The nose is the chief feature of resem-

[13] Dating back to the Tübingen days.

[14] "I spent many evenings at their home, where William (Ramsay) enlivened the company with songs, which in later years were greeted with enthusiastic applause by his students at social evenings of the University College Students' Club. . . . He had a very good voice, played his own accompaniments, and was an expert whistler."—Oho Hehner, a friend.

[15] "Another amusement of Ramsay's was sketching in water colors, an art in which he possessed no inconsiderable share of the talent which belongs to his cousins, Sir Andrew Ramsay's family."—Sir James Dobbie.

blance in the annexed representation. Wurtz and Schukenberger are both Alsations and of course are much more gemüthlich than the echter Französe, but on the whole the fellows I have got to know are very pleasant. Some of the younger lot and I kneipe every evening. Then we bathe every day too in fine stormy water.[16] Eh bien, what is there to say of more? I am going straight back to Glasgow on Wednesday by the special steamer to Glasgow. My money is about done, so I must bolt. . . . By the way I forgot to tell you that I had the cheek to read a communication on picoline, in French, which was received with loud applause. There was some remarks made afterwards very favorable, tho' I say it as shouldn't say it. Adoo. Write to Glasgow and tell me wie geht's.

Yours very Sincerely,

W. Ramsay.

[16] "He (Ramsay) was a very strong and graceful swimmer and could dive further than any amateur I have seen. When we were in Paris in 1876 the four of us used to go to one of the baths in the Seine every forenoon, and after the first time, when Ramsay was ready to dive, the bathman would pass round the word that the Englishman was going to dive, and everyone in the establishment, including the washerwoman outside, would crowd in and take up positions to watch him. He dived the whole length of the bath and sometimes turned there under water and came back a part of the length."—H. B. Fyfe, a life-long friend.

A POSSIBLE NEW SOURCE OF FOOD SUPPLY

By Professor P. W. CLAASSEN

CORNELL UNIVERSITY

MUCH attention has been given during the last few years to the question of foods. We have learned to use in our bakings and to like on our table various substitute flours that hitherto were not considered worthy of trial. Many of the flours have proved to be palatable and nourishing.

Among the many products which the Indians have taught us to use may be mentioned such common and now indispensable foods as corn and potatoes. Probably when man first sampled potatoes he did not relish them, but gradually learned to like them. Likewise the white man has learned to use corn and both corn and potatoes are now considered indispensable foods.

There are, however, many products which the Indians used and relished that have received little or no attention from the white man. The common cat-tail (*Typha*) is one of these products. Parker,[1] in speaking of the "Iroquois Uses of Maize and other Food Plants," says:

> The roots of the cat-tail were often used. Dried and pulverized the roots made a sweet flour useful for bread and pudding. Bruised and boiled fresh, syrupy gluten was obtained in which cornmeal pudding was mixed.

Others have spoken of the possibility of the cat-tail plant as a source of food supply. J. D. Hooker, in his "Descriptive and Analytical Botany," page 827, says: "The pollen of *Typha* (cat-tail) is made into bread by the natives of Scind and New Zealand." And again the botanists, Engler and Prantl, state that "the rhizome rich in starch may serve as food material."

The vast areas of cat-tail have been little utilized. Here is a plant with prolific growth, rich in starch and other products of food value, growing in situations now regarded as waste lands.

The cat-tail is a perennial plant with large underground rootstalks or rhizomes. Several of these rhizomes originate from a single plant. They spread in all directions and run underground for distances of twelve to thirty inches or more, then suddenly turn and come out and form other stalks. Thus

[1] Museum Bulletin 144, N. Y. State Museum.

A Typical Cat-tail Marsh.

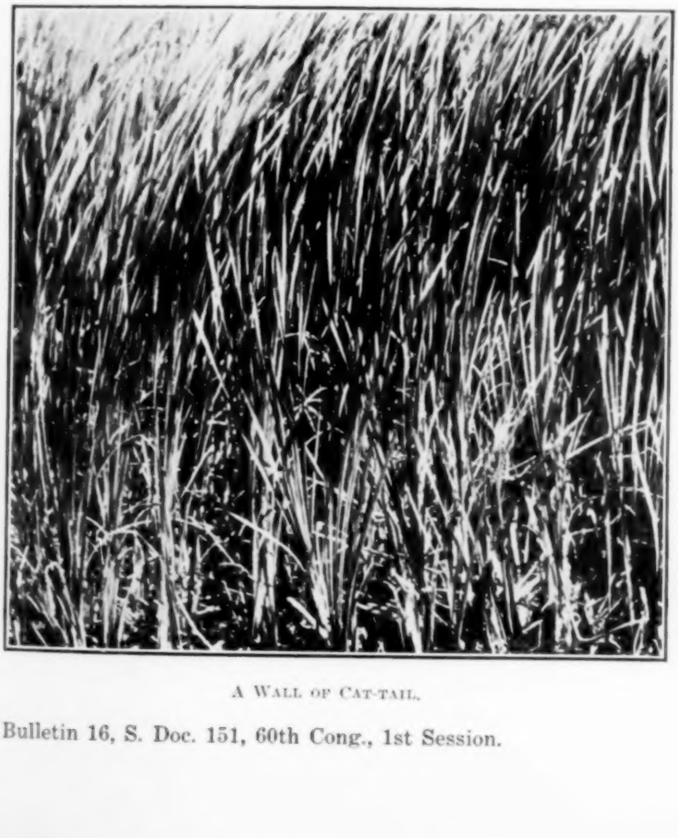
in any cat-tail patch three to four inches under the surface of the ground one finds an irregular network of these rhizomes. To these rhizomes are attached the roots and root-hairs which gather the food material from the soil. The rhizomes, which measure three fourths to one inch in diameter, are the storing places for the reserve food that has been manufactured by the green leaves. The center of the rhizome consists of a core of more solid material, an almost solid mass of starch. This core measures three eighths to one half inch in diameter. Surrounding this core of starch one finds a layer of spongy tissue, such as occurs around the roots of many of the swamp plants. It serves as a protection or as an insulator to the central core of the reserve food material.

During the growing season the cores of the rhizomes become filled with grains of starch. With this bountiful supply of reserve food material on hand, the cat-tail is able to send forth its new leaves the following spring just as soon as the frost is out of the ground. A remarkably rapid growth is thus insured. However, in this process of food manufacturing and storing, the cat-tail is not so different from many other plants. All plants store up food material in some form or another. The potato concentrates its food material in the tuber in the ground preparatory to the following year's crop. The sole purpose of this large starch supply in the potato is to provide enough reserve material for the young plant till it is able to maintain itself. Likewise the cat-tail provides for its "progeny." It is nature's way of insuring the maintenance of its species.

Man has taken advantage of many of the stored products of nature and come to depend upon them largely for his sus-

tenance, but there is still much food going to waste in so far as man's own interests are concerned. The cat-tail produces a surprisingly large amount of food material. The plant grows in situations which are at present little or not at all utilized. According to C. A. Davis,[2] there are in the United States, exclusive of Alaska, 139,855 square miles of swamp land. Thousands of acres of this land are cat-tail marshes. These marshes annually produce thousands of tons of food material. Only indirectly has man learned to reap some benefit from these cat-tails, for annually scores and scores of muskrats are trapped in the marshes. The sustenance of these muskrats consists largely of the rhizomes of the cat-tail.

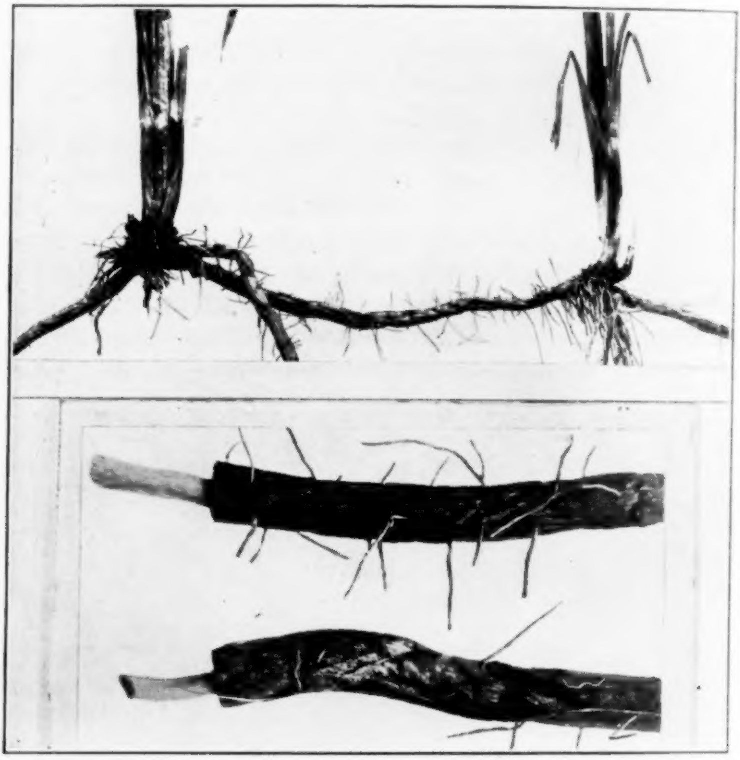
Knowing that the Indians had made use of the cat-tail as a food, and knowing that such animals as muskrats thrive on this food, it was thought worth while to investigate the value of the cat-tail plant as a source of food supply. Should it prove to be of value and should it be possible or practicable to obtain the food and prepare it in some form, it might prove to be another valuable asset in this or in some other country. With an ordinary pickaxe a square yard of cat-tails were dug up in a mod-



A Wall of Cat-tail.

[2] Bulletin 16, S. Doc. 151, 60th Cong., 1st Session.

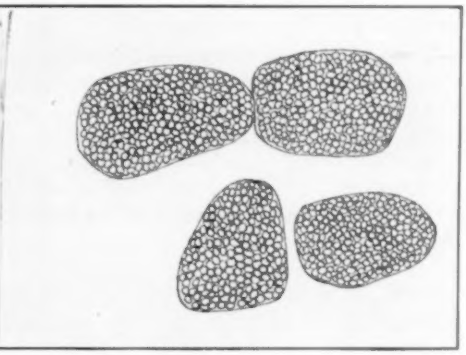
erately thick patch. The tops of the plants were cut off, the rhizomes washed and taken to the laboratory. Here the entire bundle of rhizomes was weighed. Thus the total weight of rhizomes obtainable from a square yard was found. This amounted to 6.7 pounds. Much of this weight, however, was water. The rhizomes were put upon a radiator and left till they were thoroughly dry. This required from five to eight



TWO CAT-TAIL PLANTS SHOWING THE UNDERGROUND STEMS OR RHIZOMES. Note the new offsets at the bases of the old plants.
TWO PIECES OF RHIZOME WITH PART OF THE OUTER COVERING REMOVED TO SHOW THE RELATIVE SIZE OF THE CENTRAL CORE FROM WHICH THE FLOUR IS DERIVED.

days. The dry weight of the rhizomes was 2.23 pounds, or one third of the original weight. Calculating from these figures we find that one acre of cat-tail would yield a total dry weight of rhizomes of 10,792 pounds. The next part of the problem was to determine what part, by weight, of the rhizome consisted of the central core of starch. Various methods were employed in attempting to separate the central core from the surrounding layer of spongy tissue. It was found that while

the rhizomes were still wet the spongy tissue peeled off quite readily, in fact it could be stripped off very much in the manner that one strips off the bark of a small tree. This left the central core quite clean. If, however, the rhizomes were left till partly dry the outer layer would not separate so easily and much of the core was lost in attempting to separate the two. But if the rhizomes were left till completely dry the outer layer came off very readily and left the clean, hard central core. Careful weighings showed that in the dried rhizome the central core constituted 60 per cent. of the total weight of the rhizome. Taking 60 per cent. of the above 10,792 pounds, we find that one acre would yield 6,475 pounds of material composed of the cores. These cores contain many fibers, and our next attempts were made to separate these fibers from the rest of the material. The cores were ground up and the grindings placed in water, thus attempting to separate the starch from the fibers



CROSS SECTION OF A RHIZOME. Except for the fibers the cores are composed of a solid mass of starch.

A FEW CELLS FROM THE CENTRAL CORE MUCH ENLARGED TO SHOW THE GRAINS OF STARCH.

by gravity. This method, however, did not prove satisfactory since much of the starch went into solution and few of the fibers came to the surface. A syrupy solution also forms which tends to hold the grains of starch and the fibers together. Secondly, the dried cores were ground up finely by passing them several times through an ordinary meat grinder and then sifting through a fine mesh sieve. Much of the fibrous material was thus got rid of. The siftings proved to be a fine flour of a white or slightly creamy-white color and not much different in general appearance from wheat flour. By this crude method of separating the fibrous material from the cores we found that from 10 to 15 per cent. by weight of the cores proved to be fibrous material, leaving a net weight of 5,500 pounds of the

siftings or flour available per acre. Of course, not all of the fibrous material was got rid of by this method, but likewise part of the flour was lost with the fibers, so that the above figures probably represent a fair average estimate.

A sample of the flour thus obtained was sent to Washington to the Food Administration office. This office turned the sample over to the Plant Chemical Laboratory, where an analysis of the flour was made. This analysis shows the following composition:

Moisture	7.35 Per Cent.
Ash	2.84 Per Cent.
Fat	0.65 Per Cent.
Protein	7.75 Per Cent.
Carbohydrates	81.41 Per Cent.

Mr. J. A. LeClerc, the chemist in charge, in his report on the analysis says:

> You will see from this that this material has approximately the same amount of protein that is found in rice and corn flours. The ash content is very high, however. In this respect it approximates the amount found in potato flour and in cassava flour and in dasheen flour. The fat content is somewhat lower than that found even in wheat flour. In view of our experience on the use of flour substitutes in baking we see no reason why cat-tail flour could not be used to the extent of 10 to 20 per cent. as part substitute for wheat flour.

Two samples of the flour were also analyzed by the Food Laboratory of the University of Kansas. Sample no. 1 consisted of the flour just as the cores were ground up without attempting to remove the fibers. Sample no. 2 had the fibers removed similarly to the sample that was sent to Washington. These two samples show the following composition:

	No. 1, Per Cent.	No. 2, Per Cent.
Moisture	6.77	8.78
Ash	2.37	2.48
Protein	5.71	7.22
Fat (ether extract)	3.71	4.91
Carbohydrates (different)	83.81	79.09

It may be of interest to show in tabular form the analyses of several flours in order to compare them to the cat-tail flour. The figures in these tables for the flours other than cat-tail have been taken from Bulletin 701, U. S. Department of Agriculture, Washington, D. C.

CHEMICAL ANALYSIS OF WHEAT-FLOUR SUBSTITUTES AND OF CAT-TAIL FLOUR.

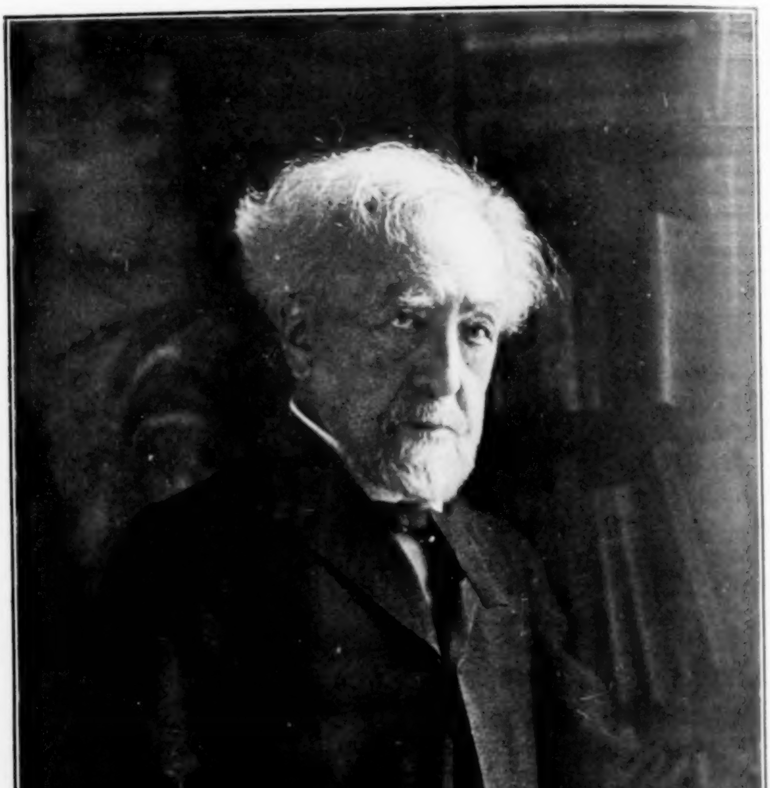
Kind of Flour	Water, Per Cent.	Ash, Per Cent.	Fat, Per Cent.	Protein, Per Cent.	Carbohydrates, Per Cent.
Spring wheat	12.00	.42	1.00	12.50	73.83
Yellow corn (raw)	6.96	.82	2.82	7.88	80.83
Rice (polished)	9.65	.36	.24	8.81	80.74
Potato (dried)	6.82	4.01	.43	12.25	74.80
Cassava	8.21	1.60	.29	1.44	86.45
Dasheen (peeled)	7.48	4.12	.46	8.00	77.80
Cat-tail (Washington analysis)	7.35	2.84	.65	7.75	81.41
Cat-tail no. 1, Univ. of Kans. anal.	6.77	2.37	3.71	5.71	83.81
Cat-tail no. 2, Univ. of Kans. anal.	8.78	2.48	4.91	7.22	79.09

A comparison of the above analyses shows that the cat-tail flour is not so different in composition from other flours and could probably well be used.

The practicability of obtaining the flour from the field is a question which deserves further attention and experimentation. Likewise the question of cultivation would require careful investigation. The fact, however, remains that there are thousands of acres of cat-tails containing considerably over two tons of flour per acre which at present finds no use.

We have found that it is not so difficult to get the flour in small quantities. Half an hour at digging and "peeling" has yielded three or four cupfuls of flour. The digging is not so different from digging potatoes and the peeling about equally facile.

We have used this flour in several ways, first as part substitute flour in baking, and secondly as a substitute for cornstarch in puddings. Biscuits made with 33 per cent. and 50 per cent. cat-tail flour were found to be very palatable. Even 100 per cent. cat-tail flour made biscuits that were not so different from biscuits made from wheat flour. Puddings made with cat-tail flour in them in place of corn starch proved to be entirely satisfactory. The flavor produced by this flour is pleasing and palatable.



Dr. Abraham Jacobi

THE PROGRESS OF SCIENCE

DR. ABRAHAM JACOBI

In the death of Dr. Abraham Jacobi the medical profession and New York City lose "the good physician" and a fine personality linking them with the middle of the last century. He had practised medicine in New York for sixty-five years and had witnessed and assisted in causing the great changes that have taken place during that period, both in his profession and in the city. Dr. Jacobi occupied the first chair for the diseases of children in the United States, having been appointed professor at the New York Medical College in 1860, and maintained to the end of his long life leadership in all matters concerned with the medical treatment and hygienic care of children.

Abraham Jacobi was born eighty-nine years ago in a Westphalian village, of Jewish parents, his father having been a peddler and keeper of a small shop. By his own efforts and ability he made his way through school and university, taking part as a medical student in the revolutionary activities of 1848. After two years of imprisonment, he came to the United States. Under the circumstances a subsequent call to a chair in the University of Berlin was a notable tribute.

When Dr. Jacobi first came to New York, he opened an office in which the fee was twenty-five cents, but his medical training, such as at that time could not be obtained in this country, and his remarkable personality soon gave him prominence in the profession. Dr. Stephen Smith, one of the editors of the *New York Journal of Medicine*, who celebrated his ninety-sixth birthday recently, invited him to write for the journal, and from that time forward he became a constant contributor to medical literature. His first book was a treatise on the diseases of women and children, prepared in cooperation with Dr. Emil Noeggeratt, and published in 1859. This was followed by other volumes and monographs, mainly concerned with the diseases of children, but also treating cancer, diphtheria and intestinal diseases.

After the closure of the New York Medical College, Dr. Jacobi became a member of the faculty of the New York Medical College, and in 1870 became clinical professor of the diseases of children in the College of Physicians and Surgeons of Columbia University, which chair he occupied until his retirement as professor emeritus in 1902. Dr. Jacobi had been connected as visiting physician with a number of public hospitals in New York City, the fiftieth anniversary of his continuous service at the Mount Sinai Hospital having been celebrated in 1910.

Dr. Jacobi was always active in medical organization, having been president of the American Medical Association, the Association of American Physicians, the New York Academy of Medicine and other societies. He took part throughout his life in all movements for the welfare of the community, more especially in those concerned with the housing, food and care of infants and children.

On the occasion of Dr. Jacobi's seventieth birthday a *Festschrift* containing scientific contributions by fifty-three colleagues was presented to him at a largely attended dinner. On his eightieth birthday the Medical Society of the State of New

Unveiling of the Statue of Ezra Cornell

York held a reception in his honor, and presented to him a bronze medallion portrait. Preliminary arrangements had already been made for the celebration of his ninetieth birthday, which would have occurred on May 6 of next year.

In 1873, Dr. Jacobi married Dr. Mary C. Putnam, a physician of distinction, active in promoting the medical education of women, who died in 1906.

At the dinner in honor of Dr. Jacobi's seventieth birthday, referred to above, the following verses by the late Dr. S. Weir Mitchell were read:

That kindly face, that gravely tender look,
Through darkened hours how many a mother knew!
And in that look won sweet reprieve of hope,
Sure that all Earth could give was there with you.

THE SEMI-CENTENNIAL OF CORNELL UNIVERSITY

CORNELL UNIVERSITY was chartered in 1865 and opened in 1868. The celebration of its completion of fifty years was postponed on account of war conditions and took place at the recent commencement with some four thousand alumni in attendance. The principal exercises were held out of doors when addresses by President Schurman, Governor Smith, Judge Hiscock, and Justice Hughes were delivered in the Schoellkopf Stadium. The speakers spoke from a platform, built large enough to hold a glee club, and fitted with an effective sound amplifier that carried the voices perfectly.

Another occasion of interest was the unveiling of the statue of Ezra Cornell by his daughter, after which President Schurman and Professor Crane paid tribute to the character and work of the founder of the university. The statue has been placed between Morrill and McGraw Hall. The illustration here reproduced gives a glimpse of the beautiful outlook from the Cornell Campus.

Each college and several departments held conferences of alumni and faculty to discuss educational problems. The opinion seemed general among those who attended that the conferences were distinctly successful, and that, contrary perhaps to the prevalent opinion when the plan was first announced, the alumni were sympathetic, encouraging, and alert to the educational work of the university. A special reunion brought back some sixty physicists to do honor to Edward L. Nichols, '75, the retiring head of the department of physics, who during the thirty-two years of his professorship has done great service for education at Cornell and research throughout the country.

It is said that a record was established by serving a course dinner to four thousand alumni in the Drill Hall, and a supper of the same magnitude was served the following evening. Miss Mary Louise Thatcher, a graduate of the Home Economics Department, who is not yet twenty-six years of age, was responsible for the arrangements, and five hundred men and women students volunteered to do the tasks of waiting on the tables.

There were many fraternity and class reunions and the usual athletic events, including a display of airplanes. One event usual at such celebrations was lacking, for Cornell has the distinction of not conferring honorary degrees.

Cornell University, somewhat removed from the Atlantic seaboard, occupies also educationally a position intermediate between the eastern private corporations and the state universities. The governor and other state officers are trustees, and the State College of Agriculture is conducted in cooperation with the university. Women are admitted on equal terms, and attention has been

paid to practical studies. Perhaps it meets as nearly as any university the conditions of Ezra Cornell's oft-quoted words: "I would found an institution where any person can find instruction in any study."

THE AMERICAN FEDERATION OF LABOR ON SCIENTIFIC RESEARCH

At the recent Atlantic City Convention of the American Federation of Labor a resolution was passed as follows:

WHEREAS, scientific research and the technical application of results of research form a fundamental basis upon which the development of our industries, manufacturing, agriculture, mining, and others must rest; and

WHEREAS, the productivity of industry is greatly increased by the technical application of the results of scientific research in physics, chemistry, biology and geology, in engineering and agriculture, and in the related sciences; and the health and well-being not only of the workers but of the whole population as well, are dependent upon advances in medicine and sanitation; so that the value of scientific advancement to the welfare of the nation is many times greater than the cost of the necessary research; and

WHEREAS, the increased productivity of industry resulting from scientific research is a most potent factor in the ever-increasing struggle of the workers to raise their standards of living, and the importance of this factor must steadily increase since there is a limit beyond which the average standard of living of the whole population can not progress by the usual methods of readjustment, which limit can only be raised by research and the utilization of the results of research in industry; and

WHEREAS, there are numerous important and pressing problems of administration and regulation now faced by federal, state and local governments, the wise solution of which depends upon scientific and technical research; and

WHEREAS, the war has brought home to all the nations engaged in it the overwhelming importance of science and technology to national welfare; whether in war or in peace, and not only is private initiative attempting to organize far-reaching research in these fields on a national scale, but in several countries governmental participation and support of such undertakings are already active; therefore be it

Resolved, by the Amedican Federation of Labor in convention assembled, that a broad program of scientific and technical research is of major importance to the national welfare and should be fostered in every way by the federal government, and that the activities of the government itself in such research should be adequately and generously supported in order that the work may be greatly strengthened and extended; and the Secretary of the Federation is instructed to transmit copies of this resolution to the President of the United States, to the president pro tempore of the Senate, and to the speaker of the House of Rrepresentatives.

THE PROPOSED MEDICAL FOUNDATION FOR NEW YORK CITY

ANNOUNCEMENT has been made by Dr. Royal S. Copeland, health commissioner of New York City, of an organization to be known as the New York Association for the advancement of Medical Education and Medical Science.

The association's constitution and by-laws have already been adopted and an application has been filed at the Secretary of State's office in Albany for a charter. Dr. Wendell C.

Phillips, ear specialist and general surgeon for Bellevue Hospital, is the president, and Dr. Haven Emerson, formerly health commissioner of New York, is the secretary.

Dr. Phillips, who is the originator of the project, planned before the war for an institution that would at least rival Vienna and Berlin. The world conflict postponed the matter, but as soon as the armistice was signed the physician and those interested with him revived the plan. A meeting was held on April 10, at which prominent medical men gave their views, and a committee was appointed to deal with the matter.

As stated in the constitution of the association, there are four primary objects to be attained. There are: First: To improve and amplify the methods of graduate and undergraduate teaching. Second: To perfect plans for utilizing the vast clinical material of the city for teaching purposes and to make use of teaching talent now unemployed. Third: To bring about a working affiliation of the medical schools, hospitals and laboratories, as well as the public health facilities of the city, to the end that the best interests of medical education may be conserved. Fourth: To initiate the establishment of a medical foundation in New York City whereby funds may be secured to meet the financial requirements of all forms of medical education and investigation.

There will be two classes of membership in the organization, one a general membership, including all physicians in good standing, teachers of auxiliary sciences, and investigators of problems relating to medicine; the other, a corporate membership of medical teachers and medical men with hospital appointments or affiliations. The corporate membership is limited by the constitution to not over 150.

The physicians who are responsible for the plan issued a short statement, which was given out at the board of health offices, in which they said:

> For years it has been evident that medical education, both undergraduate and graduate in New York has not adequately represented the possibilities of this great city. One of the reasons for this state of affairs has been the lack of financial support for our medical institutions. A more potent reason, however, arises from the fact that individual institutions working along somewhat narrow lines have accomplished satisfactory general results. The larger possibilities which could only come from a more or less central organization have failed to materialize.
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> As a result, men seeking medical education have been obliged to seek medical centers in European countries where more individual and special courses could be secured with but little trouble.
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> It is a historical fact that after every great war, the medical center of the world is changed and the war just over will be no exception to the rule. In line with these ideas and in order to give New York City this opportunity to at least become one of the leading teaching medical centers of the world, our organization has been formed.

In addition to Dr. Phillips and Dr. Emerson, the following compose the officers of the association: Dr. George D. Stewart, president of the New York Academy of Medicine, first vice-president; Dr. Glentworth Butler, chief medical consultant of the Long Island College Hospital, second vice-president; Dr. Arthur F. Chace, stomach specialist of the Post-Graduate hospital, treasurer. The trustees are Colonel Charles H. Peck, Dr. William Francis Campbell, Dr. John E. Hartwell, Dr. Frederick Tilney, Dr. Otto V. Huffman, Dr. Adrian Lambert, Dr. Samuel A. Brown, Dr. James Alexander Miller, and Dr. George W. Kosmak.

SCIENTIFIC ITEMS

WE record with regret the death of Lord Rayleigh, the great English

physicist, and of Emil Fischer, the distinguished chemist of the University of Berlin.

Dr. George E. Hale, director of the Mount Wilson Observatory and foreign secretary of the National Academy of Sciences, who has been for the last ten years a correspondent of the Paris Academy of Sciences, has been elected a foreign associate, taking the place of Adolph von Baeyer, declared vacant by the academy. The foreign associates are limited to twelve, and the distinction has been held by only two Americans—Simon Newcomb and Alexander Agassiz.

Professor Albert A. Michelson, head of the department of physics at the University of Chicago, has been appointed to the rank of commander, U.S.N.R.F. He served as lieutenant commander in the Bureau of Ordnance of the Navy Department at Washington during the war.

Colonel J. G. Adami, F.R.S., professor of pathology, McGill University, Montreal, has been elected vice-chancellor of the University of Liverpool, in succession to Sir Albert Dale.

The eighty-seventh annual meeting of the British Association will be held in Bournemouth from September 9 to 13, under the presidency of the Honorable Sir Charles Parsons, who will deliver an address dealing with engineering and the war. The following presidents of sections have been appointed by the council: A, Mathematical and Physical Science, Professor Andrew Gray; B, Chemistry, Professor P. Phillips Bedson; C, Geology, Dr. J. W. Evans; D, Zoology, Dr. F. A. Dixey; E, Geography, Professor L. W. Lyde; F, Economic Science and Statistics, Sir Hugh Bell, Bart.; G, Engineering, Professor J. E. Petavel; H, Anthropology, Professor Arthur Keith; I, Physiology, Professor D. Noel Paton; K, Botany, Sir Daniel Morris; L, Educational Science, Sir Napier Shaw, and M, Agriculture, Professor W. Somerville. Evening discourses will be delivered by Sir Arthur Evans on "The palace of Minos and the prehistoric civilization of Crete"; and by Mr. Sidney G. Brown on "The gyroscopic compass."

An alumni memorial to honor Dr. C. R. Van Hise, late president of the University of Wisconsin, has been proposed in the form of a Van Hise Memorial Geological Building to be erected on the campus to bring together under one roof the departments of geology and mining engineering, as well as the state and national geological surveys.